WHY DOES THE MOON-LANDING HOAX STILL EXIST?

All About Space

FUTURE TECH

HOW TO AVOID AN ASTEROID IMPACT

SECRETS OF BLACK HOLES

THE TRUTH ABOUT THE COSMOS' MOST MIND-BENDING PHENOMENA

HOW DID EARTH GET ITS WATER?

BUZZ ALDRIN

MOON & NIGHT SKY TOUR

SPECIAL FEATURE

HOW MANY STARS ARE IN THE UNIVERSE?

Q&A WITH NASA & MORE

EXPERTS SOLVE SPACE'S GREATEST MYSTERIES

REVIEWED

CANON 10x42L IS WP BINOCULAR

FUTURE
ISSUE 128

EVERYTHING YOU NEED TO KNOW ABOUT URANUS

CELESTRON

NEW!

ASTRONOMY MADE SIMPLE

FIRSTSCOPE

FIRSTSCOPE'S wide field-of-view provides bright, sharp views of the Moon's mountains and craters in crisp detail. You'll also enjoy using the FirstScope to pan the Milky Way, explore open star clusters, marvel at Saturn's rings, or view favorite deep-sky objects like the Orion Nebula.

SIMPLE and portable design that's easy to use for astronomers of all levels - a great choice for kids and families.

COMPACT and lightweight makes it an ideal entry-level astronomical telescope.

QUALITY dobsonian-style telescope features a spherical glass mirror with a generous 76mm of aperture.

Model shown: Royal Observatory Greenwich FirstScope 76 RRP £89.99

In association with ROYAL OBSERVATORY GREENWICH

For more information visit shop.rmg.co.uk Contact Celestron at enquiries@celestron.com

WELCOME

Issue 128

5 ISSUE HIGHLIGHTS

Black holes

From how they form to how they're detected: the secrets of these mysterious objects revealed 16

Great space mysteries

Our panel of experts reveals what the likely explanation is for some of the cosmos' weirdest wonders 34

The Moon-landing hoax

Why does this conspiracy theory continue to rage on? 50

Binocular review

Does the Canon 10x42L IS WP offer stable views? 92

Free space history books

Worth £30, learn about NASA, the Space Race and heroes of space 95

This month we delve into the secrets of perhaps the most mysterious phenomena in the cosmos: black holes. Predicted in 1916 by Albert Einstein, we've come a long way into understanding these high-gravity objects - especially since the advent of the Event Horizon Telescope, a global network of radio dishes that sprang into action and captured the first direct image of a black hole in 2019. The composition of the supermassive object at the centre of elliptical galaxy Messier 87, which rests some 54 million light years away, excited the world and provided additional evidence for black holes' existence. We've continued to build on our understanding of these fascinating objects since, as you'll discover in our cover feature. Head over to page 14 for all of the details.

Elsewhere in the issue, our panel of experts answers your questions about the cosmos and has a crack at explaining some pretty strange occurrences within it - from where all the antimatter went to what causes gravity; what formed Saturn's rings to whether white holes exist!

Enjoy the read. I hope you enjoy our fact-packed issue, and I'll look forward to seeing you next time. Wishing you clear skies!

GEMMA LAVENDER
CONTENT DIRECTOR

56 SUBSCRIBE TO ALL ABOUT SPACE TODAY AND YOU'LL RECEIVE

Great savings off the cover price
Every issue delivered straight to your door or digital device before it arrives in the shops
Exclusive subscriber-edition covers

INSIDE

16 SECRETS OF BLACK HOLES

THE TRUTH ABOUT THE UNIVERSE'S MOST MYSTERIOUS PHENOMENA

95 CLAIM YOUR FREE GIFTS

Heroes of Space
Book of the Space Race
History of NASA

LAUNCHPAD

06 News from around the universe

FUTURE TECH

26 Distant target analysis
When it comes to protecting Earth from impacts, it's crucial to know what asteroids are made of

INTERVIEW

28 Fedor Šimkovic
Šimkovic, an ESET Science Award laureate, reveals what studying neutrinos can reveal about the cosmos

FOCUS ON

32 New atomic clock loses just one second every 300 billion years

34 Space mysteries
The truth is out there, according to astrophysicists, planetary scientists and astronomers

FOCUS ON

42 Ryugu samples reveal asteroid's inner workings

PLANET PROFILE

44 Uranus
The ice giant has fascinated explorers for decades

FOCUS ON

48 Did Mars' deep interior cause a loss of its atmosphere?

50 Moon-landing hoax
Why does the theory still live on?

FOCUS ON

58 How did Earth get its water?

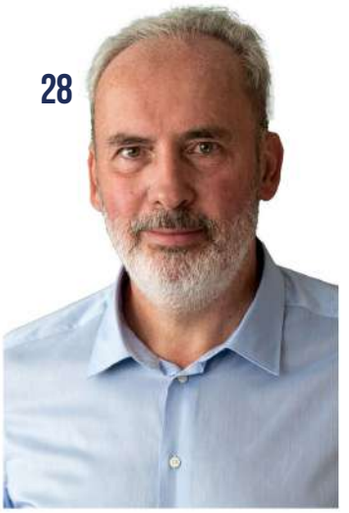
60 Killer universe
Relatively safe in our protective bubble, some forces could end life on Earth forever. Is the universe out to get us?

FOCUS ON

66 Very Large Telescope finds new supermassive black hole

68 How many stars are in the universe?
With a fleet of missions scouring the cosmos, will it ever be possible to come to an estimate?

74 Ask Space
Your questions answered by our panel of experts



STARGAZER

78 What's in the sky?

82 Month's planets

84 Moon tour

85 Naked eye & binocular targets

86 Deep sky challenge

88 The Northern Hemisphere

90 Astroshots

92 Binocular review

96 In the shops

WIN!
A CELESTRON SKYMASTER 20x80
WORTH OVER £160
15

AUGMENTED REALITY

Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include these features

When you see the AR 'Scan Here' logo on the page, use your phone to scan the QR code, which looks like this

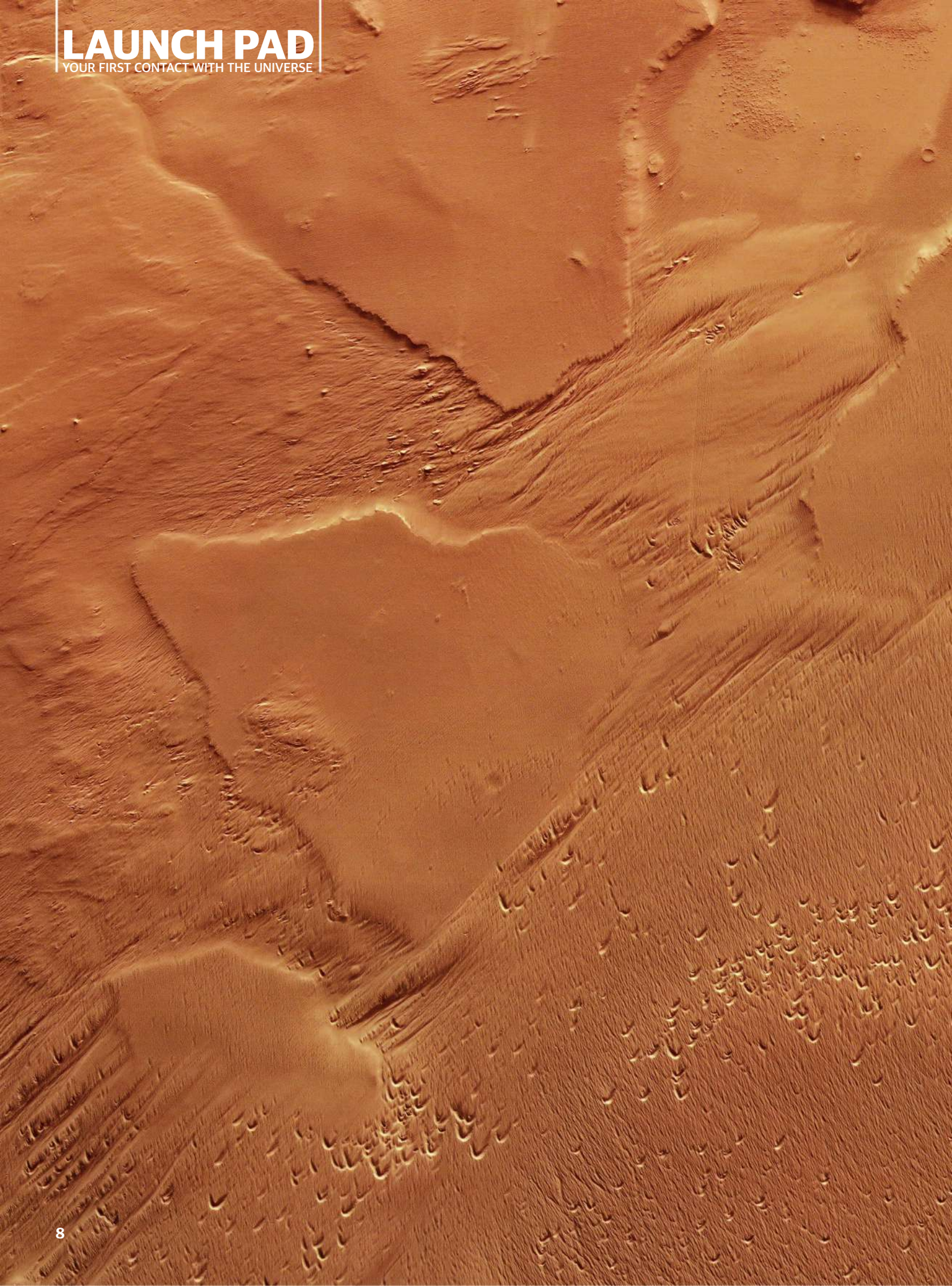
Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to function

1 MARCH 2022

Webb to target Orion's bar

The James Webb Space Telescope will zero in on a portion of the Orion Nebula, the closest region of mass star formation to Earth, to learn more about how massive young stars shape their environments. The Orion Nebula, 1,350 light years from Earth, is known as a stellar nursery. Dense clouds of gas and dust in this region collapse into stellar embryos that gradually grow bigger until the pressure and heat in their cores is enough to trigger nuclear fusion. Because of the amount of dust, the hearts of stellar nurseries are obscured from optical telescopes. But infrared light, in which Webb will observe the universe, can penetrate those clouds and reveal the secrets of star formation.

© NASA, ESA

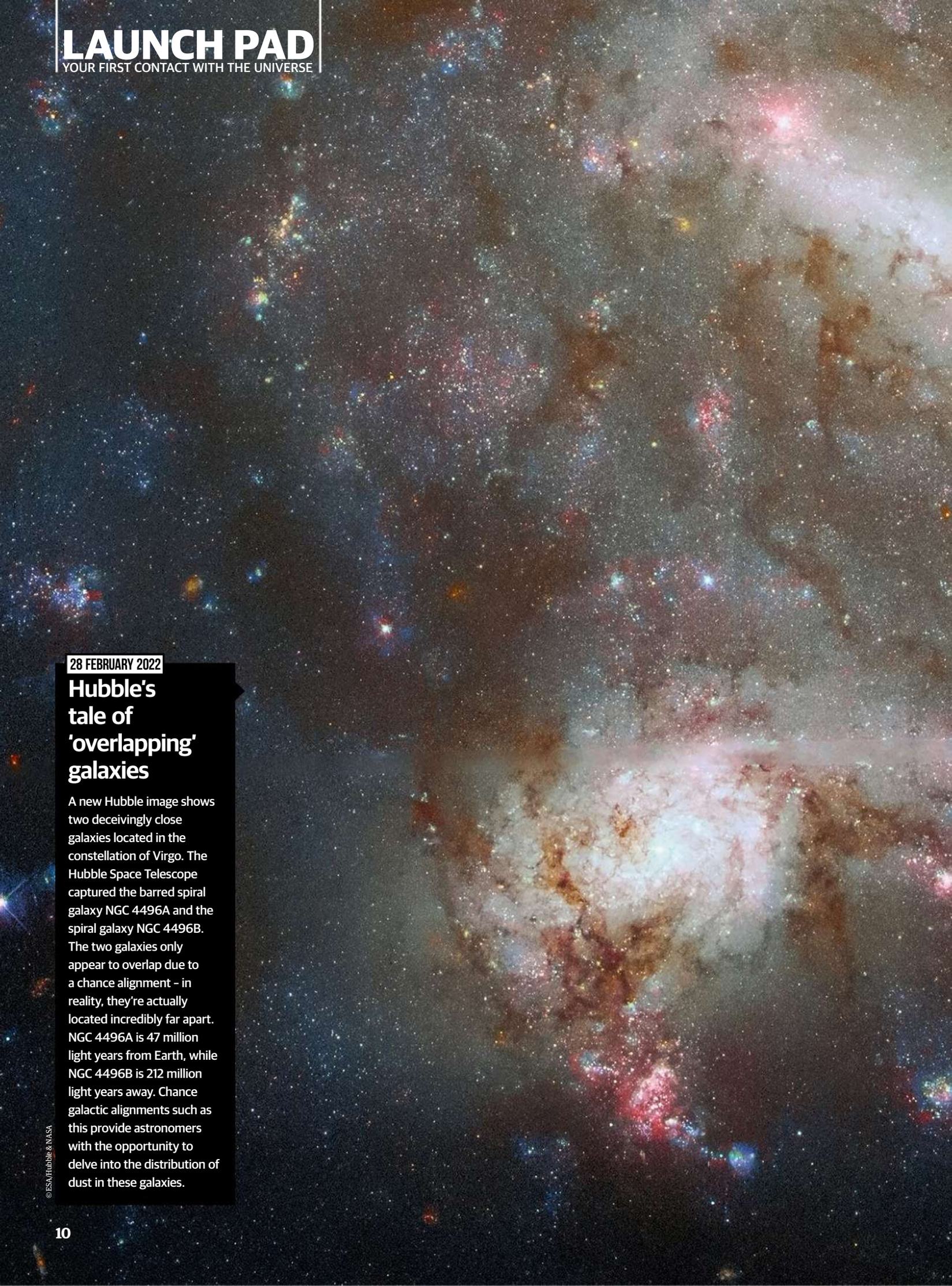


23 FEBRUARY 2022

Martian wind at work

An enormous dust deposit on Mars shows the power of Martian wind. On the surface of Mars is possibly the largest single dust source on the Red Planet: the Medusae Fossae Formation. Shaped and sculpted by blowing winds over time, this mound of dust and surface material stretches out over 5,000 kilometres (3,100 miles) and lies nestled between Tharsis and Elysium, the planet's most prominent volcanic areas. The European Space Agency's Mars Express orbiter captured the Medusae Fossae Formation in all its dusty, windy glory. The formation is named for Medusa, the Gorgon from Greek mythology who could turn anyone to stone with a single glance.

© ESA



28 FEBRUARY 2022

Hubble's tale of 'overlapping' galaxies

A new Hubble image shows two deceivingly close galaxies located in the constellation of Virgo. The Hubble Space Telescope captured the barred spiral galaxy NGC 4496A and the spiral galaxy NGC 4496B. The two galaxies only appear to overlap due to a chance alignment – in reality, they're actually located incredibly far apart. NGC 4496A is 47 million light years from Earth, while NGC 4496B is 212 million light years away. Chance galactic alignments such as this provide astronomers with the opportunity to delve into the distribution of dust in these galaxies.

© ESA/Hubble & NASA

SPACE FORCE PLANS TO SEND A PATROL PROBE OUT PAST THE MOON

Words by Chelsea Gohd

The US military is planning to extend its reach in space to one day patrol the area around the Moon. In a new video, the US Air Force Research Laboratory (AFRL) revealed the military's big plans for future work in space. These plans, the video showed, include extending space awareness capabilities beyond geostationary orbit with the help of a new satellite called the Cislunar Highway Patrol System (CHPS). This is a Moon-patrolling probe that the military plans to launch to cislunar space, a vast area around Earth that stretches out past the Moon's orbit.

"Until now, the United States space mission extended 22,000 miles [35,400 kilometres] above Earth," the video states, referring to the altitude at which geostationary satellites fly. "That was then; this is now. The Air Force Research Laboratory is extending that range by ten times and the operations area of the United States by 1,000 times, taking our reach to the far side of the Moon into cislunar space, far beyond the crowd," the video's narrator continued.

CHPS is "a spaceflight experiment designed to demonstrate foundational space domain awareness capabilities in the cislunar regime," according to the AFRL website. The lab will carry out the satellite's development as part of the CHPS program. The probe will then be acquired by the US Space Force to be used by the US Space Command, which oversees military activity and operations in space.

So what will the US military do with a satellite way out past the Moon? "It's the first step for them to be able to know what's going on in cislunar space and then identify any potential threats to US activities," Dr Brian Weeden, director of program planning for the nonprofit Secure World Foundation, said about the program. Weeden specified that he doesn't think the probe will be used to respond to threats in space, but rather for observational purposes.

AFRL's video points to efforts by agencies like NASA to return to the Moon's surface and other "interplanetary destinations" as part of the impetus to stretch the military's surveillance reach to cislunar space. The video states that these missions to the Moon and beyond will be "increasing space traffic to the Moon many times over the coming decades." CHPS "will bypass thousands of government and commercial satellites as it makes its way to a rarely-before-visited domain 272,000 miles [438,000 kilometres] from Earth," the video adds.

"The US Space Force will ensure the peaceful development of space, keeping our missions safe and secure in these distant frontiers," the video states. "The responsible use of space and unfettered access to space domain awareness ensures collision avoidance, on-orbit logistics, communication, navigation and manoeuvring, all critical to the US and allied space commerce, science and exploration." The AFRL will issue a request for prototype proposals for the CHPS satellite on 21 March and reveal whose proposal won the contract in July, the lab shared.

Below: It's the first step to be able to know what's going on in cislunar space and identify any potential threats to US activities

© Getty

VENUS' EXTREME SURFACE HEAT DRIVES SWIRLING WINDS IN UPPER ATMOSPHERE

Words by Chelsea Gohd

Using infrared and visible measurements from Galileo National Telescope in the Canary Islands and the European Space Agency's Venus Express orbiter, scientists have shown how the swirling winds and searing heat on Venus work together in a revealing new study by the University of Lisbon in Portugal. The surface of Venus is hot enough to melt lead, with temperatures averaging 467 degrees Celsius (872 degrees Fahrenheit).

This extreme heat is maintained by a thick atmosphere of carbon dioxide that traps the heat on the planet in a greenhouse effect. This atmosphere also sports acid sulphuric clouds and a perpetual, swirling windstorm. In the new study, researchers revealed new insights into the planet's strange wind and heat. "Winds accelerate as we move upward to increasing altitudes, but we don't yet know why," said Pedro Mota Machado, a researcher at the University of Lisbon. "This study throws much light on this."

The team studied the speed of Venus' wind at two different heights, about 20 kilometres (12 miles) apart in the planet's atmosphere. They observed and tracked the clouds at one-hour intervals, and using indirect methods calculated the speed of the wind pushing the clouds. They found that the winds were a whopping 150 kilometres (93 miles) per hour faster at the higher altitude at the top of the clouds than winds at the lower altitude.

© NASA/JPL-Caltech

Above: Venus captured by NASA's Mariner 10 spacecraft

NEW SKY MAP SHOWCASES MORE THAN 4 MILLION GALAXIES AND OTHER OBJECTS

Words by Elizabeth Howell

Millions of new objects have just been catalogued in a vast new sky map that will lead to more investigations about our universe's environment. A map of roughly one-quarter of the northern sky was generated using a pan-European set of telescopes called the Low-Frequency Array, or LOFAR. It detected objects that are, for the most part, billions of light years away and include objects ranging from galaxies to distant stars.

The LOFAR scientists created an interactive animation of the huge sky map, as well as a vast database for the public to search for individual objects. "We anticipate [the survey] will lead to many more scientific breakthroughs in the future," said Timothy Shimwell, a researcher at the Netherlands Institute for Radio Astronomy and Leiden University.

Possible investigations include "examining how the largest structures in the universe grow, how black holes form and evolve, the physics governing the formation of stars in distant galaxies and even detailing the most spectacular phases in the life of stars in our own galaxy," Shimwell added.

Of the vast set, roughly 1 million of the objects were not known to astronomy before, the team said. What's more, the entire set was catalogued in radio waves, giving a unique view of many objects that were already known to science that were viewed in other wavelengths. A healthy dose of machine learning was required to parse roughly eight petabytes of data – a single petabyte represents 1,000 terabytes. The team used novel data-processing algorithms on high-performance computers across Europe to process all the information, which was collected across 3,500 hours of observations.

© LOFAR/ ASTRON

Below: The LOFAR 'superterp'. Part of the core of the extended telescope located near Exloo in the Netherlands

HOW IT WORKS

subscription offer

FROM £3.00 PER ISSUE!

PRINT

DIGITAL

PRINT & DIGITAL

This offer is **only** available via our online shop

www.magazinesdirect.com/HIW/A12J

NASA'S ARTEMIS 1 MOON MISSION WON'T LAUNCH UNTIL MAY

Words by Mike Wall

© NASA

Above: A close-up view of NASA's Artemis 1 Space Launch System megarocket inside the Vehicle Assembly Building at NASA's Kennedy Space Center in Florida

An April launch is no longer possible for NASA's Artemis 1, which will send an uncrewed Orion spacecraft around the Moon using the huge Space Launch System (SLS). And May could be difficult to hit as well, according to agency officials. "We continue to evaluate the May window, but we're also recognising that there's a lot of work in front of us," said Tom Whitmeyer, deputy associate administrator for exploration systems development at NASA headquarters in Washington.

Some of that work will involve analysing data from the Artemis 1 'wet dress rehearsal', a crucial test that will take the SLS-Orion stack through many of the milestones it will hit on launch day. Like the launch, the wet dress rehearsal will take place on Pad 39B at NASA's Kennedy Space Center (KSC) in Florida. SLS and Orion are scheduled to roll out to the pad from KSC's cavernous Vehicle Assembly Building (VAB) in March. It'll likely take about 12 hours for the huge vehicle to make the relatively short trek to the pad.

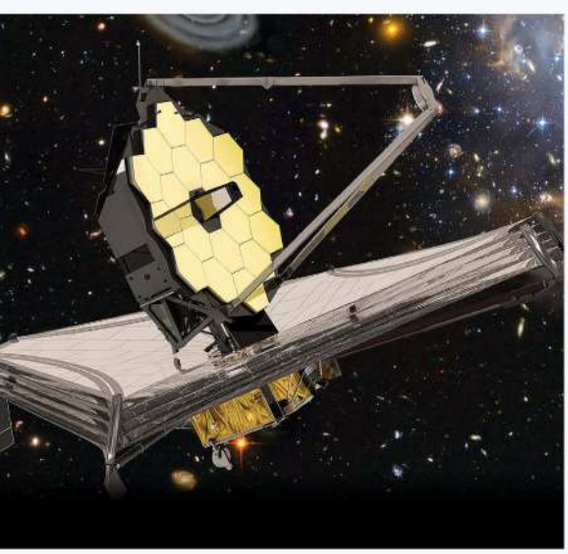
The May launch window runs from the 7th through the 21st. If Artemis 1 isn't ready to go by then, the next opportunity comes from 6 through 16 June. The next window after that runs from 29 June through 12 July. These windows are limited for a variety of reasons: performance constraints on the SLS, the need to line the launch up properly with Earth's rotation and the position of the Moon and the fact that the solar-powered Orion isn't designed to fly through eclipses that last longer than 90 minutes, among other factors.

THE JAMES WEBB SPACE TELESCOPE WILL MAP HALF A MILLION EARLY GALAXIES

Words by Stefanie Waldek

NASA's James Webb Space Telescope will continue observations during its first year of operations in a program called COSMOS-Webb. Founded in 2002, the Cosmological Evolution Survey (COSMOS) originally utilised the Hubble Space Telescope to image an area of the sky equivalent to ten Moons wide.

The program later grew to include ground-based observatories working across multiple wavelengths of light. "COSMOS has become the survey that a lot of extragalactic scientists go to in order to conduct their analyses because the data products are so widely available – and because it covers such a wide area of the sky," said the Rochester Institute of Technology's Jeyhan Kartaltepe, assistant professor of physics and coleader of the COSMOS-Webb program.



© NASA

Left: Artist's impression of Webb in space

Right: Artist's impression of the X-ray binary system containing a black hole, the small black dot at the centre of the accretion disc, and a companion star

Taking over 200 hours of observation time during its first year, Webb will image half a million early galaxies for the survey. It will use its Near-InfraRed Camera (NIRCam) to map a subset of Hubble's COSMOS field about three full Moons in size. Webb will also map a separate, smaller area with its Mid-InfraRed Instrument (MIRI).

The goal of COSMOS-Webb is threefold: to examine the Epoch of Reionisation and the very earliest stars, to search for early fully evolved galaxies and to study the evolution of the mysterious substance scientists call dark matter within galaxies' stellar content. "We will also look for some of the rarest galaxies that existed early on, as well as map the large-scale dark matter distribution of galaxies out to very early times," said Caitlin Casey, an assistant professor at the University of Texas at Austin and coleader of the COSMOS-Webb program.

IN COOPERATION WITH SPACE.com

STRANGELY TILTED BLACK HOLE CHALLENGES FORMATION THEORIES

Words by Teresa Pultarova

A tilted black hole spinning around a misaligned axis has been discovered in our galaxy. The black hole and its companion star form a system called MAXI J1820+070, some 10,000 light years from Earth. The system was first spotted by NASA's Chandra X-ray Observatory in 2018. But recent optical observations by the Nordic Optical Telescope in the Canary Islands revealed the black hole behaves in ways that defy expectations.

By studying the orientation of the jets of ionised matter emitted from the black hole's poles, Juri Poutanen of the University of Turku in Finland found that the black hole spins around an axis that's tilted by at least 40 degrees towards the plane in which the black hole orbits its companion star, the largest misalignment ever reported. The question remains what caused the misalignment in MAXI J1820+070. The scientists believe that contrary to current models of black hole formation following supernova explosions, the black hole in MAXI J1820+070 must have received a 'kick' during the explosion that gave rise to it.

© Stockholm University / R. Hynes

WIN

CELESTRON SKYMASTER 20x80

WORTH £160

This brilliant binocular will provide stunning high-definition views day and night

If you're looking for a rich, high-resolution experience when watching the night sky – or even for daytime terrestrial observing – there's no better resource to have in your arsenal than a good binocular. The Celestron SkyMaster 20x80 is of a superior quality, fitted with high-quality BAK-4 prisms and multi-coated optics for exquisite views. Designed to bring the sight of distant objects into incredibly clear and sharp focus – whether you're watching the local wildlife or uncovering the members of the beautiful Pleiades star cluster – these binoculars are ideal for seasoned astronomers and those just getting started in observing, while the lightweight design provides an excellent opportunity to establish a 'grab-and-go' approach to astronomy.

To be in with a chance of winning, answer this question:

When was Pluto demoted to a dwarf planet?

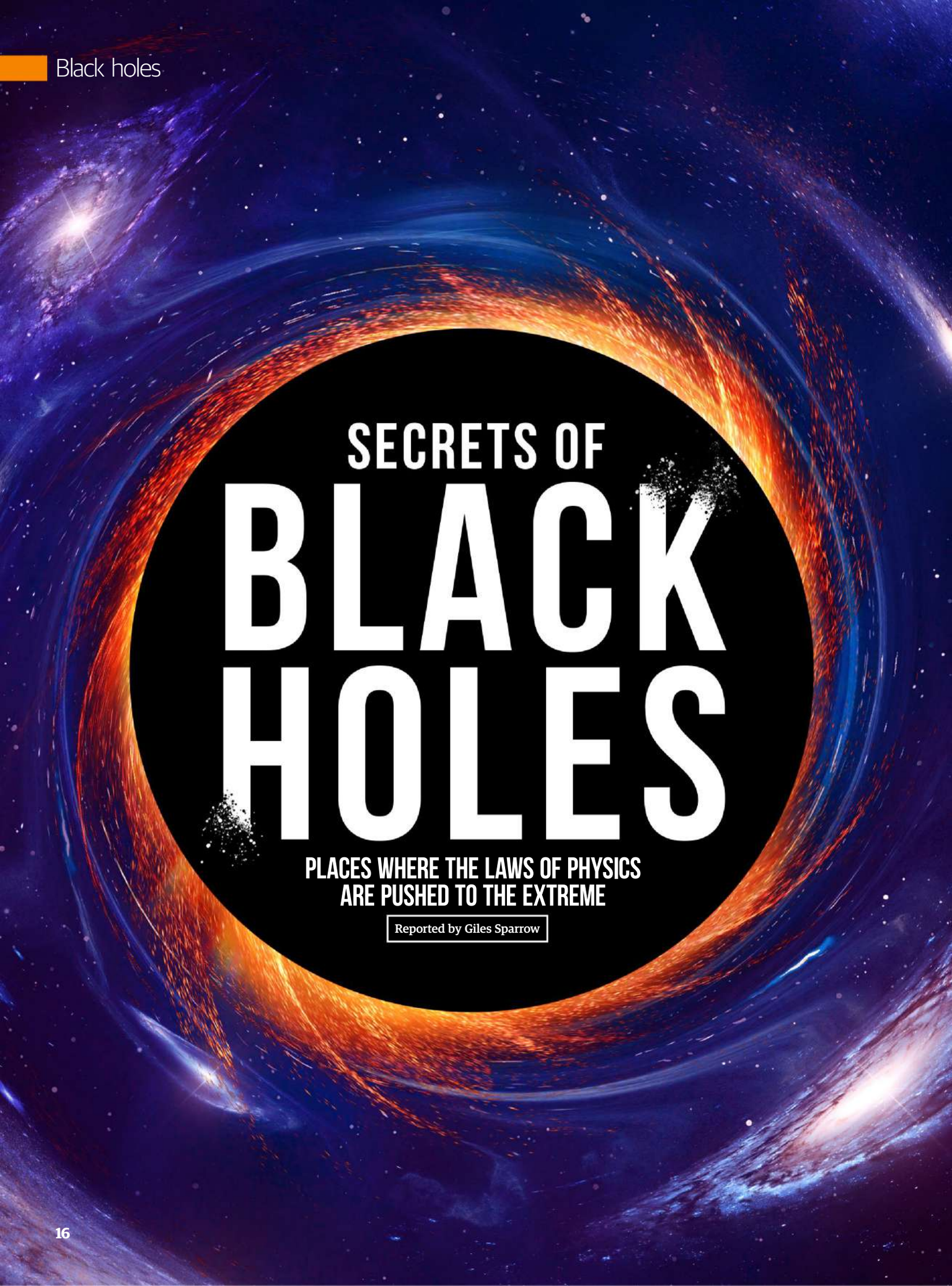
A: 2021 **B:** 2016 **C:** 2006

Competition ends on 21 April 2022

Enter online at **surveymonkey.co.uk/r/AAS128**

Visit the website for full terms and conditions at **futureplc.com/terms-conditions**

CELESTRON



SECRETS OF BLACK HOLES

PLACES WHERE THE LAWS OF PHYSICS ARE PUSHED TO THE EXTREME

Reported by Giles Sparrow

Black holes are the most mysterious objects in the universe. They're places where physics is pushed to its most extreme, where light cannot escape and where space-time itself is twisted and even punctured, leading to the most incredible and counter-intuitive phenomena. A black hole is a region of space where gravity is so strong that nothing, not even light, can escape from its grasp. Within a certain proximity of one, closer than the black hole's 'event horizon', you'd have to travel faster than light to get away from it. Since nothing can go faster than light – at least as far as scientists know – then whatever falls down a black hole stays down the black hole.

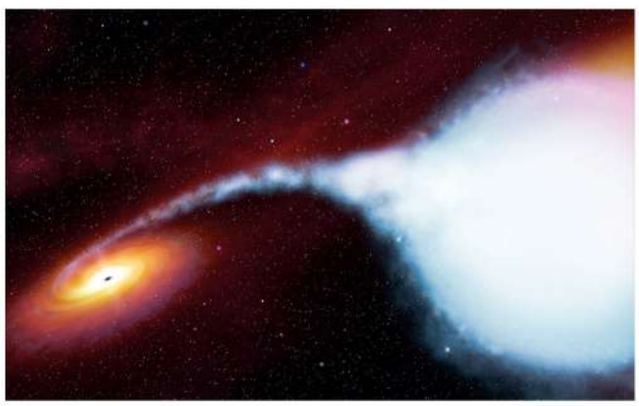
The discovery of black holes dates back to Einstein's general theory of relativity. Einstein himself didn't predict the existence of black holes per se, but general relativity, which describes mass, space, time and gravity, provides the mathematical foundations for understanding them. These were realised by Einstein's German compatriot Karl Schwarzschild, who solved Einstein's equations to describe the gravitational field around a non-rotating, spherical mass and to determine the Schwarzschild radius, which is the size of a black hole's event horizon. In the 1960s, Roy Kerr solved Einstein's equations for a more realistic scenario – that of a black hole that's spinning.

We've already mentioned that light cannot escape a black hole, and the event horizon is its ultimate boundary of no return. Once something has crossed the event horizon's invisible boundary, it can never return from the black hole. Let's picture what is going on using an oft-mentioned analogy, that of a rubber sheet, which we have to imagine as being the fabric of space for this analogy to work. If you want to try this at home, a bedsheet held tight at each corner should suffice. Place a marble onto the sheet. In our example, that's Earth. Notice how it causes the sheet to dip a little. In general relativity, that dip in the fabric of space is called a gravitational well – it represents Earth's gravitational field. Now put a tennis ball on the sheet, imagining that it's the Sun. You'll notice that it creates a bigger dip than the 'Earth', not necessarily because it's larger, but because it has more mass. If you were to zip ball bearings past both the marble and the tennis ball, they'd need more energy to get past the tennis ball without falling into its steeper gravitational well.

Now, put a cannonball on the rubber sheet – if you're trying this at home you probably don't have a cannonball to hand, but see if you can use something suitably heavy. It will create a dip so steep that once any ball bearings you roll in its direction get too close to it, they'll always fall into the dip and cannot get out no matter how fast they are moving. Around a real black hole, the event

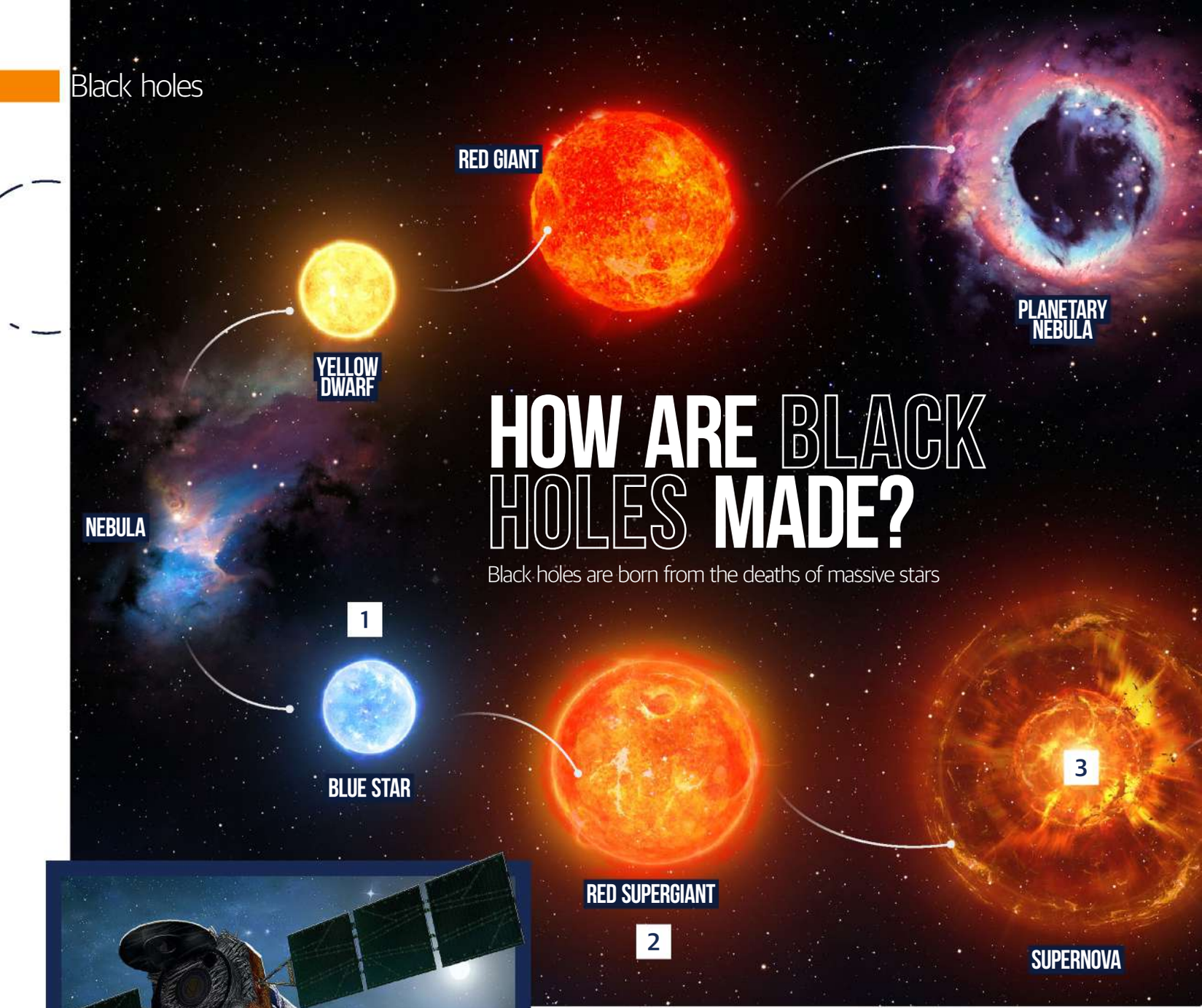
THEY'RE A MASSIVE X-RAY SOURCE

The first observational evidence for a black hole emerged in 1971, coming from a binary star system within our own galaxy. Called Cygnus X-1, the system produces some of the universe's brightest X-rays. These don't emanate from the black hole itself, or from its visible companion star, which is enormous at 33 times the mass of our own Sun. Instead matter is constantly being stripped from the giant star and dragged into an accretion disc around the black hole, and it's from this accretion disc that the X-rays are emitted. As was the case with HR 6819, astronomers used observed star motion to estimate the mass of the unseen object in Cygnus X-1. The latest calculations put the dark object at 21 solar masses, concentrated into such a small space that it couldn't be anything other than a black hole.



© ESA

© Getty



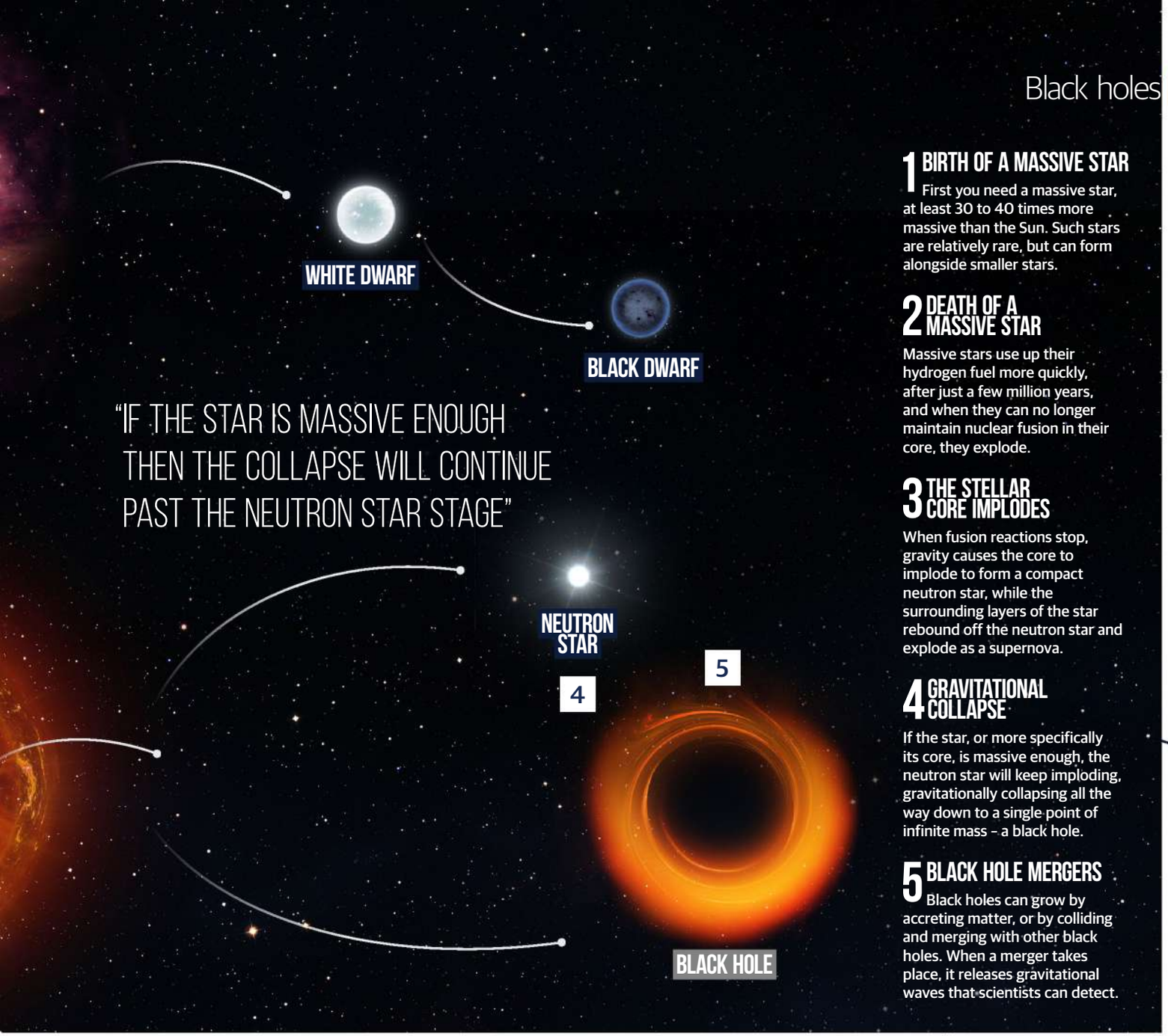
© NASA

Above: Advanced space telescopes might be able to image black holes – or at least their surrounding material

horizon is the distance from the black hole where the dip is so steep that not even light can move fast enough to escape. And that's why black holes are black.

There's so much more to tell about the story of black holes. How are they formed? Where do the things that fall into them go? What exists at the centre of a black hole? And what do black holes do in the centres of galaxies? Let's continue with the easier bit – how they are formed. When our Sun, a star, reaches the end of its life in about 5 billion years, it will expand to become a red giant before gracefully puffing off its outer layers to form a planetary nebula, leaving behind its small, hot core, called a white dwarf. Stars more than eight times the mass of the Sun, however, bow out more explosively. Their huge masses ultimately cause their cores to collapse due to the internal pull of their own gravity, while the rest of the star goes supernova. As the outer parts of the star explode, the collapsing core condenses to become a neutron star, which is so tightly packed that it contains as much, or more, mass as the Sun but is only 20 kilometres (12.4 miles) or so across. If the star is massive enough – at least 30 to 40 times the mass of the Sun – then the collapse will continue past the neutron star stage, imploding and collapsing down to a point of infinite density, the 'singularity' at the heart of a black hole.

In mathematics, singularities are calculations that tend to infinity, usually because of some error, some gap in our knowledge needed to fully complete the equation. This also describes the black hole singularity, in the sense that we don't know the necessary physics to figure the singularity out. That's because at the microscopic scale of the black hole singularity, we enter the world of quantum physics, and scientists don't yet have a theory of quantum gravity. Until we



1 BIRTH OF A MASSIVE STAR

First you need a massive star, at least 30 to 40 times more massive than the Sun. Such stars are relatively rare, but can form alongside smaller stars.

2 DEATH OF A MASSIVE STAR

Massive stars use up their hydrogen fuel more quickly, after just a few million years, and when they can no longer maintain nuclear fusion in their core, they explode.

3 THE STELLAR CORE IMPLODES

When fusion reactions stop, gravity causes the core to implode to form a compact neutron star, while the surrounding layers of the star rebound off the neutron star and explode as a supernova.

4 GRAVITATIONAL COLLAPSE

If the star, or more specifically its core, is massive enough, the neutron star will keep imploding, gravitationally collapsing all the way down to a single point of infinite mass – a black hole.

5 BLACK HOLE MERGERS

Black holes can grow by accreting matter, or by colliding and merging with other black holes. When a merger takes place, it releases gravitational waves that scientists can detect.

do, scientists won't have the tools to be able to mathematically describe a black hole singularity.

Not that any of this prevents astronomers from learning more about what occurs outside the event horizon, where light still escapes. Some black holes can grow to be millions, or even billions of times more massive than our Sun – in case you're wondering, our Sun has a mass of 1.9×10^{30} kilograms, or 1.9 million trillion trillion kilograms. Astronomers aren't entirely sure how black holes grow to be 'supermassive' like this – it's a possibility that supermassive black holes are the result of lots of mergers of smaller black holes created by supernovae, or maybe they are formed by giant clouds of gas that existed when the universe was very young which underwent a dramatic gravitational collapse and imploded to form a massive black hole. However they form,

HOW BLACK HOLES GROW

The earliest black holes to form will be much bigger today

x3 Images © Getty

GIANT STAR

The first generation of very massive stars, hundreds of times as massive as the Sun, would have burnt through their nuclear fuel very quickly.

SEED BLACK HOLE

These stars collapsed down to black holes of tens of solar masses, which then acted as seeds for the creation of much larger black holes.

ACCRETION

Over billions of years, gas and dust spiralling into these black holes increased their mass; this isn't enough to explain supermassive black holes.

ANATOMY OF A BLACK HOLE

1 SINGULARITY
The core of a black hole is a mysterious point of infinite mass called a singularity, where our currently known laws of physics break down.

2 EVENT HORIZON
The point of no return; this is where the gravity from the extreme curvature of space-time is so strong that not even light can escape.

3 ERGOSPHERE
An oblate zone around a rotating black hole, the ergosphere is a volume of space from where energy and mass can be extracted from the black hole.

4 STATIC LIMIT
The edge of the ergosphere. Everything inside the static limit is caught up by the mass of the black hole dragging the fabric of space-time with it as it rotates.

AR SCAN HERE

THEY CAN EMIT GRAVITATIONAL WAVES

Black holes don't always exist in isolation; sometimes they occur in pairs, orbiting around each other. When they do, the gravitational interaction between them creates ripples in space-time, which propagate outwards as gravitational waves. With observatories like the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo, we now have the ability to detect these waves. The first discovery, involving the merger of two black holes, was announced back in 2016, and many more have been made since then. As detector sensitivity improves, other wave-generating events besides black hole mergers are being discovered, such as a crash between a black hole and a neutron star which took place way beyond our galaxy at a distance of 650 million to 1.5 billion light years from Earth.

© Tobias Roetsch

supermassive black holes can be found at the centres of most giant galaxies. For example, our Milky Way has a supermassive black hole at its heart called Sagittarius A*, and it has a mass 4.1 million times greater than the Sun's mass.

The huge gravitational well of supermassive black holes means that they can pull in a lot of surrounding material – gas and dust clouds, asteroids, comets and sometimes even whole stars. This material gets ripped apart by the gravitational tidal forces being wielded by the black hole and can lead to a phenomenon known as 'spaghettification'.

Imagine an unfortunate astronaut floating too close to a black hole. The tidal forces are so great that the gravity pulling on the astronaut's feet will be far stronger than the gravity pulling on their head. This would have the effect of stretching them out to the point that they would be pulled into strings of their respective atoms and molecules. Fortunately, no astronaut has ever fallen into a black hole, but plenty of gas clouds have, and they get spaghettified too.

We can see the consequences of these gas clouds being torn apart around active black holes – the material ripped from the gas clouds forms a disc of incredibly hot gas that encircles the black hole outside the event horizon. Astronomers call such discs 'accretion discs' because the gas is said to be accreting onto the black hole. Friction between the atoms and molecules in the disc, which can be moving around the black hole at high speeds, causes the gas to heat up above a million degrees Celsius (1.8 million degrees Fahrenheit) and shine brightly. So while a black hole itself is dark, the environment just outside an active black hole's event horizon can be highly luminous. Furthermore, the disc is rife with powerful magnetic fields emanating from the black hole, and these can funnel charged particles in the disc towards the black hole's

5 ACCRETION DISC
An active black hole siphons and steals matter, mostly in the form of interstellar gas, from the environment around it. This matter falls towards the black hole in a spiralling accretion disc.

6 RELATIVISTIC JET
Powerful magnetic fields weaving through the accretion disc can funnel charged particles away in beams or jets that emanate from above and below the rotational axis.

4

"FORTUNATELY, NO ASTRONAUT HAS EVER FALLEN INTO A BLACK HOLE, BUT PLENTY OF GAS CLOUDS HAVE, AND THEY GET SPAGHETTIFIED TOO"

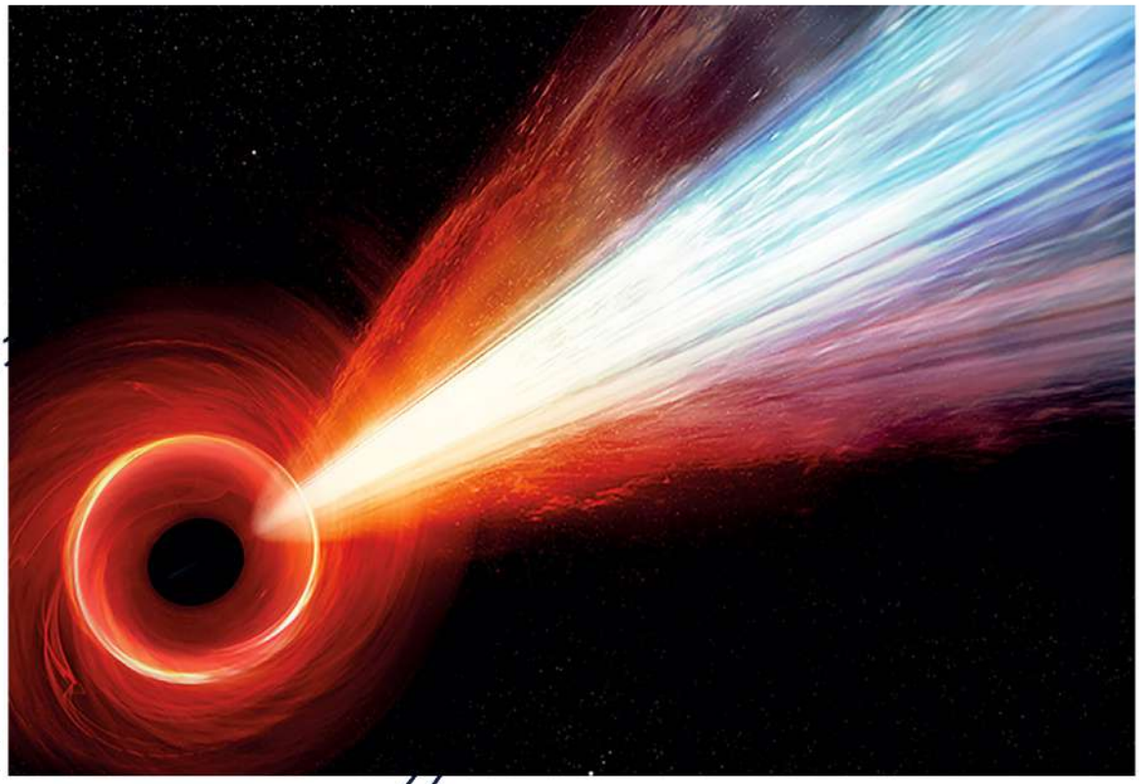
WHEN BLACK HOLES COLLIDE

MERGING GALAXIES
Two galaxies crash into each other, initially producing a confused mess of material but then settling down to become a single, merged galaxy.

TWO BLACK HOLES
The black holes that started at the centres of the original galaxies gradually spiral towards each other, eventually coalescing.

HIGH-ENERGY JET
The combined black hole may cause the core of the merged galaxy to eject streams of hot gas and high-speed particles.

VISIBLE CONSEQUENCES
The newly merged black hole gives its presence away through the release of gravitational waves and high-energy radiation.



© NASA

GAMMA-RAY BURSTS ARE EVIDENCE

In the 1930s, Subrahmanyan Chandrasekhar looked at what happens to a star when it has used up all its nuclear fuel. The end result depends on the star's mass. If the star is really big then its dense core – which may itself be three or more times the mass of the Sun – collapses all the way down to a black hole. The final core collapse happens quickly, in a matter of seconds, and it releases a tremendous amount of energy in the form of a gamma-ray burst. This burst can radiate as much energy into space as an ordinary star emits in its entire lifetime. Telescopes on Earth have detected many of these bursts, some of which come from galaxies billions of light years away, so we can actually see black holes being born.

rotational axis. The energies are so great that these particles are then magnetically beamed away from the black hole in visible jets that move at almost the speed of light. These jets, and the accretion discs they originate from, are incredibly bright, and when our line of sight is looking almost straight down one of these jets, we see a luminous object called a quasar. When we happen to be looking directly down the jet, it's even more luminous, and we call that a blazar. Regardless of what astronomers name it, the phenomenon is the same – a monster black hole that's spitting out a meal.

Some of the gas in the accretion disc does eventually find itself spiralling into the black hole. For anything approaching and crossing the event horizon, odd things happen. The warping of space-time by the mass of the black hole is so great here that something called gravitational time dilation occurs. As a person approaches the event horizon, time begins to run differently compared to the clocks belonging to observers who are watching from a distance – for example, us watching a black hole with our telescopes. A distant observer would see time stand still at the event horizon, and any astronaut crossing the event horizon would appear nearly frozen in time. The astronaut, however, would not perceive time slowing down; assuming they've somehow survived spaghettification, time will seem to proceed normally to them. It's just one of the weird consequences of general relativity.

And what of material that does fall irrevocably into a black hole? Where does it go, and can it ever come back out again? Stephen Hawking asked this question, and even made a famous bet about it. It turns out that black holes aren't truly black. Hawking became famous for the concept of Hawking radiation, which was the realisation that black holes can actually radiate particles, and even light. The secret lies in quantum field theory, which is a way of saying that on the quantum level, space is continuously fizzing with energy, spontaneously producing pairs of 'virtual' particles – one made of matter, the other of antimatter, such as a positron and an electron. They're described as 'virtual' because they usually instantly annihilate one another, as matter and antimatter do when they come into contact with one another, so they're not in existence for very long. But Hawking

DIFFERENT KINDS OF BLACK HOLE

A SMALL BLACK HOLE

Despite packing in more than 4 million times the mass of our Sun, the black hole at the centre of our galaxy is no larger than the Solar System.

THE CLOSEST BLACK HOLE

The nearest known black hole candidate is found in the triple star system HR 6819, which is 1,120 light years from Earth.

MOST MASSIVE BLACK HOLE

The heaviest of heavyweights is the supermassive black hole found in the quasar TON 618, with a mass 66 billion times greater than our Sun.

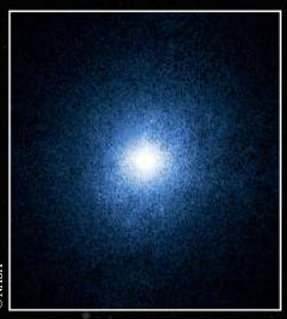
RUNAWAY BLACK HOLES

Galaxies often collide. When they do, their supermassive black holes also merge, which can give the product of the merger a kick, causing it to escape its galaxy.

MINIATURE BLACK HOLES

Some theories suggest that the Big Bang created a horde of micro black holes, with masses ranging from 100 millionths of a kilogram up to that of a small asteroid.

FAMOUS BLACK HOLES AND CANDIDATES


© NASA

CYGNUS X-1

Distance: 6,000 light years

Solar masses: 21.2

A stellar-mass black hole orbiting a blue supergiant star, from which the black hole is stealing gas that forms an accretion disc. It occasionally outbursts in X-rays.

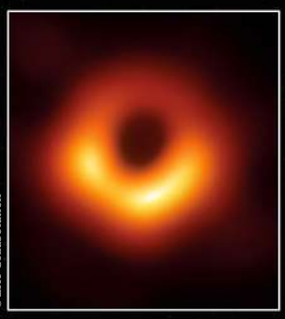
© NASA

SAGITTARIUS A*

Distance: 26,000 light years

Solar masses: 4.1 million

The supermassive black hole at the centre of our Milky Way. It's generally inactive, with only modest X-ray outbursts as it consumes small gas clouds.

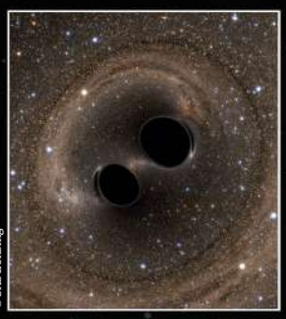

© EHT Collaboration

MESSIER 87 BLACK HOLE

Distance: 54 million light years

Solar masses: 6.5 billion

The first black hole to be imaged right down to the event horizon, revealing the black hole's 'shadow' on the surrounding accretion disc.

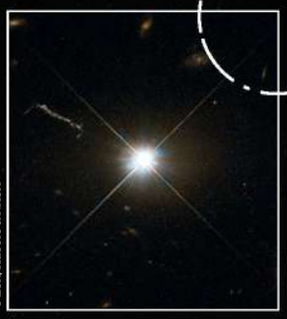

© SXS Lensing

GW150914 BLACK HOLE

Distance: 1.4 billion light years

Solar masses: 62

The product of the first black hole merger to be detected by gravitational waves formed when a 35-solar-mass black hole collided with a 30-solar-mass black hole. The extra three solar masses were converted into gravitational-wave energy.


© ESA/Hubble & NASA

3C 273

Distance: 2.4 billion light years

Solar masses: 886 million

The first quasar discovered, the black hole at its heart is hungrily guzzling gas, producing an incredibly bright accretion disc and a jet moving at almost the speed of light.

"SOME OF THE GAS IN THE ACCRETION DISC DOES EVENTUALLY FIND ITSELF SPIRALLING INTO THE BLACK HOLE"

Right: The Atacama Large Millimeter/submillimeter Array (ALMA) searches for signals of black holes

© ALMA

THE NETWORK THAT IMAGED A BLACK HOLE

These global telescopes blazed a trail for black hole imaging and revolutionised astrophysics

1 SOUTH POLE TELESCOPE
Location: Antarctica

2 ARIZONA RADIO OBSERVATORY'S SUBMILLIMETER TELESCOPE
Location: Arizona

3 JAMES CLERK MAXWELL TELESCOPE
Location: Hawaii

4 SUBMILLIMETER ARRAY
Location: Hawaii

5 LARGE MILLIMETER TELESCOPE
Location: Mexico

6 ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY
Location: Chile

7 ATACAMA PATHFINDER EXPERIMENT
Location: Chile

8 VERY LONG BASELINE ARRAY
Location: New Mexico

9 ROBERT C. BYRD GREEN BANK TELESCOPE
Location: West Virginia

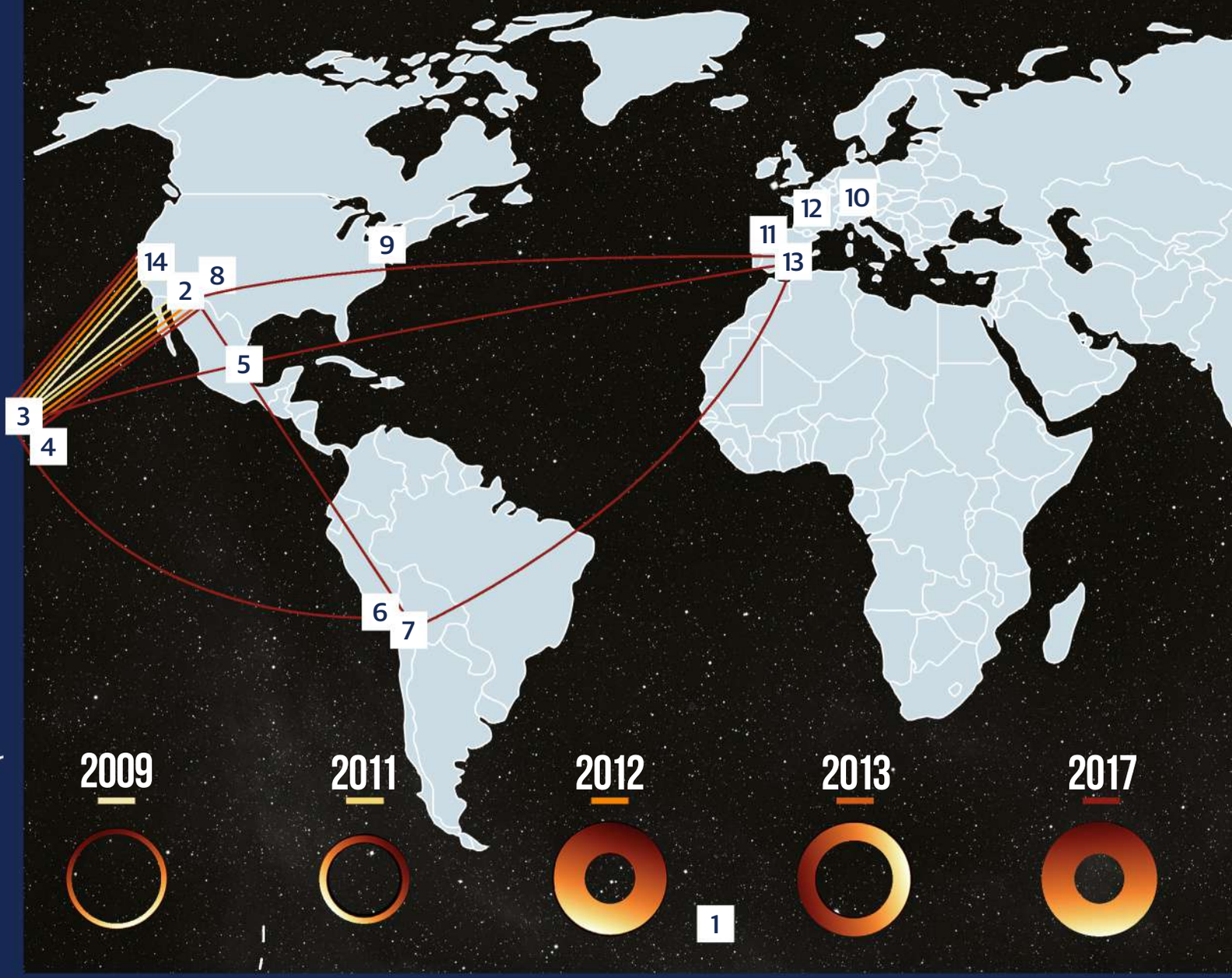
10 RADIO TELESCOPE EFFELSBERG
Location: Germany

11 YEBES OBSERVATORY
Location: Spain

12 NORTHERN EXTENDED MILLIMETER ARRAY
Location: France

13 INSTITUT DE RADIOASTRONOMIE MILLIMETRIQUE
Location: Spain

14 COMBINED ARRAY FOR RESEARCH IN MILLIMETER-WAVE ASTRONOMY
Location: California



HOW THE EVENT HORIZON TELESCOPE WORKS

The planet-sized array used cutting-edge technology to reveal the edge of a black hole

CLOAKING DEVICE

Everything inside the event horizon of a black hole is forever hidden from view, because not even light can escape. But just outside this, the matter spiralling inwards shines brightly.

1 EVENT HORIZON

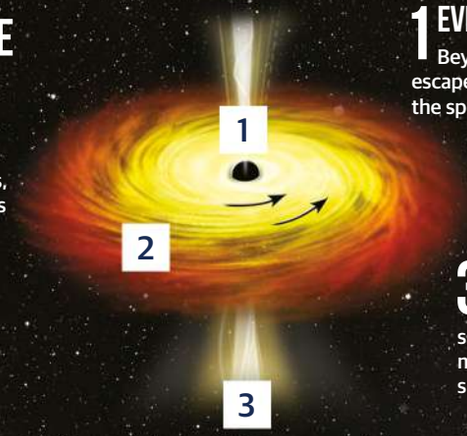
Beyond this radius, the escape velocity exceeds the speed of light.

2 ACCRETION DISC

Dust and gas gets accelerated almost to the speed of light.

3 POLAR JETS

Spinning black holes spew jets of ionised matter at relativistic speeds from each pole.



GRAVITATIONAL LENS

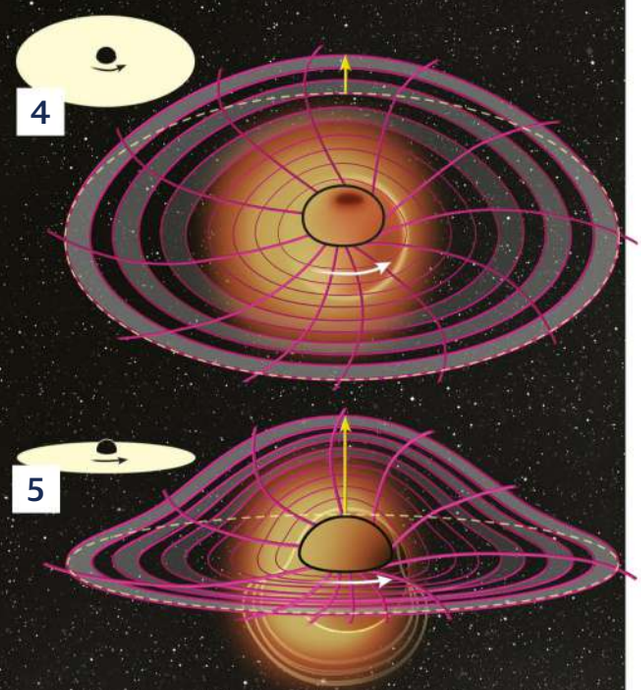
Light that passes close to the event horizon gets deflected, as if it was passing through a lens. This warps the circular accretion disc from our point of view.

4 FACE ON

If the accretion disc is nearly perpendicular to us, the gravitational lens effect is small.

5 EDGE ON

At oblique angles, the image is bent upwards, showing us behind the black hole.

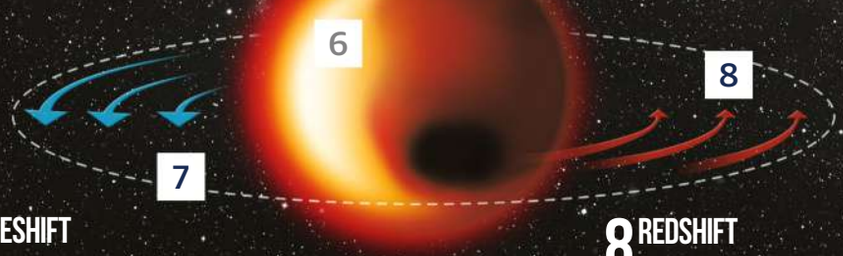


GLOWING BANANA

Matter orbits so fast close to the black hole that the radiation shifts wavelength from one side to the other, making it brighter or darker to us.

6 BRIGHTER REGION

The side shifted towards detectable wavelengths appears brighter to us.



7 BLUESHIFT

Light moving towards Earth gets squashed towards shorter wavelengths.

8 REDSHIFT

Light moving away from Earth is stretched into longer wavelengths.

© Nicholas Forder

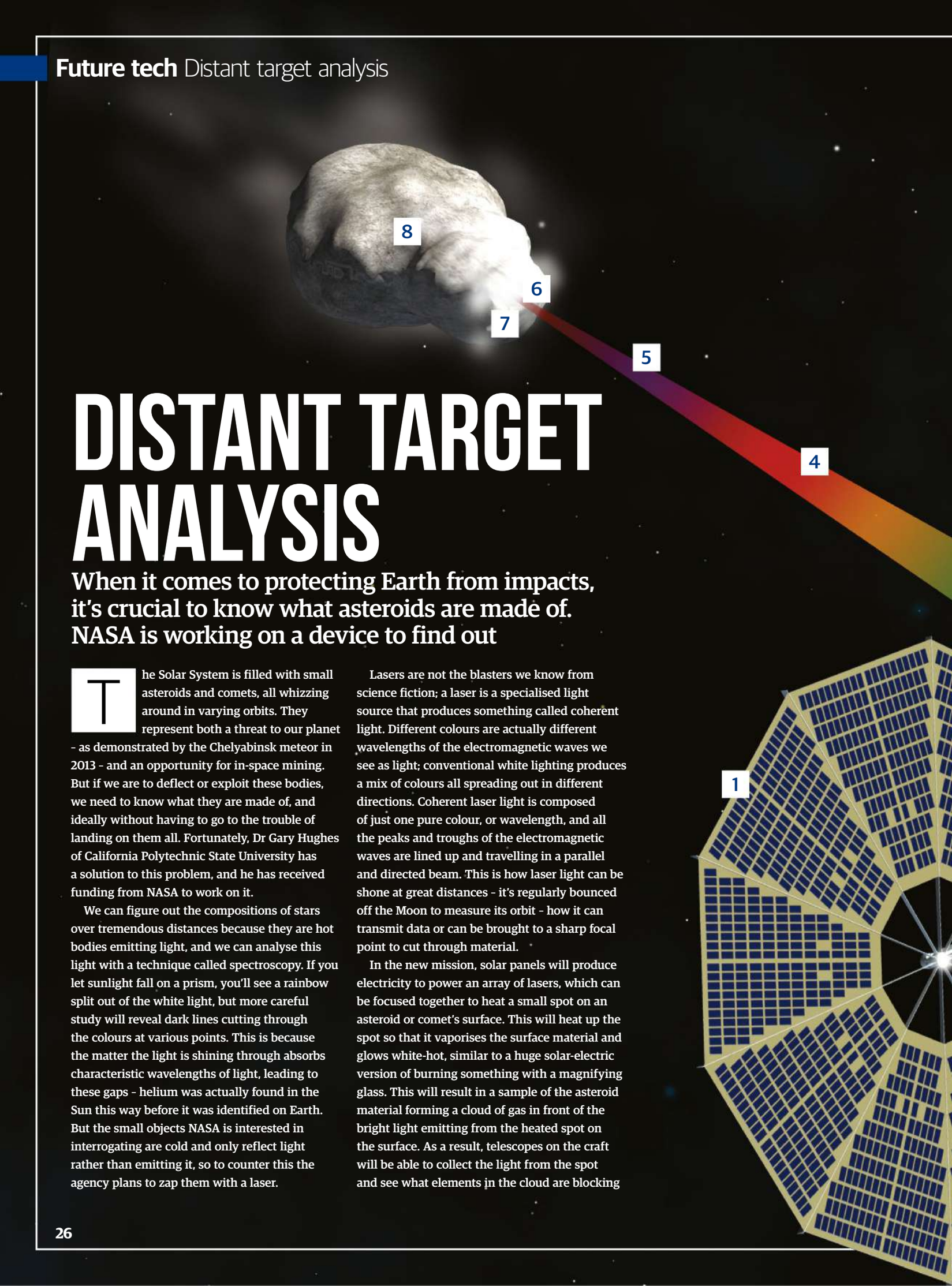
Right: Spiralling black holes on the path to a merger

© LIGO

realised that pairs of virtual particles coming into existence on the edge of the event horizon can be split up – one falls into the black hole, while the other, if it has enough energy, can race away into space and escape. Since the escaping particle has lost its antipartner, it doesn't annihilate, surviving to become a 'real' particle. Since the energy of the quantum field is drawn from the black hole's mass, the escaping particle is essentially running off with some of the mass of the black hole. Over the course of trillions and trillions of years, even the most supermassive black holes will begin to evaporate through the release of Hawking radiation.

Once a black hole evaporates, what happens to all the information of everything that went into it? This is the source of a great paradox, called the black hole information paradox, which became the focus of Hawking's famous bet with fellow physicists Kip Thorne and John Preskill. They would often make fun bets with one another, and in this particular case Hawking and Thorne bet Preskill that information inside a black hole is not preserved. In 2004 Hawking conceded the bet by agreeing that black holes do preserve information through Hawking radiation and gave Preskill a baseball encyclopaedia, 'made for the storage and retrieval of information'. Black holes fascinate us because they are so far out of our everyday experience, and there's still so much we don't know about them. When the Event Horizon Telescope took the very first image of a black hole's event horizon, around the supermassive black hole at the centre of the giant galaxy Messier 87, which is 53 million light years away, it made the front pages of newspapers. Who knows what new and bigger telescopes will discover about black holes in the future?

Giles Sparrow
Space science writer
Giles has degrees in astronomy and science communication and has written many books and articles on all aspects of the universe.



DISTANT TARGET ANALYSIS

When it comes to protecting Earth from impacts, it's crucial to know what asteroids are made of. NASA is working on a device to find out

The Solar System is filled with small asteroids and comets, all whizzing around in varying orbits. They represent both a threat to our planet – as demonstrated by the Chelyabinsk meteor in 2013 – and an opportunity for in-space mining. But if we are to deflect or exploit these bodies, we need to know what they are made of, and ideally without having to go to the trouble of landing on them all. Fortunately, Dr Gary Hughes of California Polytechnic State University has a solution to this problem, and he has received funding from NASA to work on it.

We can figure out the compositions of stars over tremendous distances because they are hot bodies emitting light, and we can analyse this light with a technique called spectroscopy. If you let sunlight fall on a prism, you'll see a rainbow split out of the white light, but more careful study will reveal dark lines cutting through the colours at various points. This is because the matter the light is shining through absorbs characteristic wavelengths of light, leading to these gaps – helium was actually found in the Sun this way before it was identified on Earth. But the small objects NASA is interested in interrogating are cold and only reflect light rather than emitting it, so to counter this the agency plans to zap them with a laser.

Lasers are not the blasters we know from science fiction; a laser is a specialised light source that produces something called coherent light. Different colours are actually different wavelengths of the electromagnetic waves we see as light; conventional white lighting produces a mix of colours all spreading out in different directions. Coherent laser light is composed of just one pure colour, or wavelength, and all the peaks and troughs of the electromagnetic waves are lined up and travelling in a parallel and directed beam. This is how laser light can be shone at great distances – it's regularly bounced off the Moon to measure its orbit – how it can transmit data or can be brought to a sharp focal point to cut through material.

In the new mission, solar panels will produce electricity to power an array of lasers, which can be focused together to heat a small spot on an asteroid or comet's surface. This will heat up the spot so that it vaporises the surface material and glows white-hot, similar to a huge solar-electric version of burning something with a magnifying glass. This will result in a sample of the asteroid material forming a cloud of gas in front of the bright light emitting from the heated spot on the surface. As a result, telescopes on the craft will be able to collect the light from the spot and see what elements in the cloud are blocking

1 SOLAR PANELS
These collect sunlight and turn it into electricity to power the spacecraft systems, including the lasers. The panels and lasers are effectively focusing the sunlight electrically.

2 CRAFT DESIGN
The main structure of the spacecraft could be based upon existing Earth satellite or space probe designs, just like how Venus Express used the same design as Mars Express.

3 LASER ARRAY
The mission would use a group of lasers, individually of quite low power, that can work together to create a small heated spot on the surface of the object.

4 ABSORPTION SPECTRA
The heated spot will radiate colours that are characteristic of the material being heated, and the gas cloud will block certain colours depending on its composition.

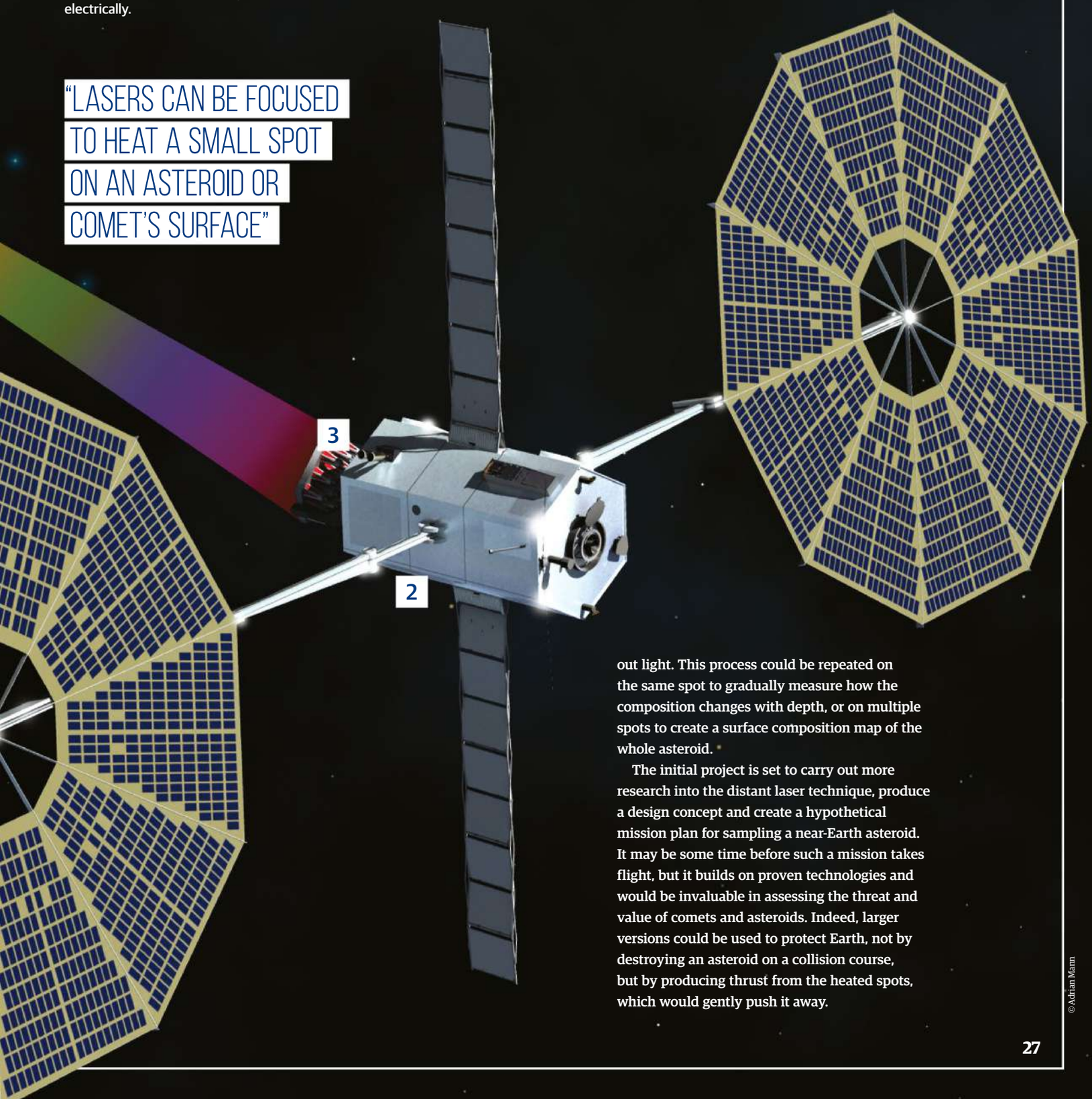
5 RETURNING LIGHT
Light emitted from the hot spot on the surface will be collected by telescopes on the craft. The light can then be analysed to see what material it's shining through.

6 MOLECULAR CLOUD
The vaporised material forms a cloud of gas between the spacecraft and the heated spot on the surface. The craft will then selectively absorb light from the spot.

7 HEATED SPOT
The lasers focus energy on a small spot, heating it to around 2,000 degrees Celsius (3,600 degrees Fahrenheit). This would vaporise the surface.

8 ASTEROID
Huge numbers of asteroids float around the Solar System. They are largely either stony or metallic, while comets are made up of a mix of ices.

"LASERS CAN BE FOCUSED TO HEAT A SMALL SPOT ON AN ASTEROID OR COMET'S SURFACE"



out light. This process could be repeated on the same spot to gradually measure how the composition changes with depth, or on multiple spots to create a surface composition map of the whole asteroid.

The initial project is set to carry out more research into the distant laser technique, produce a design concept and create a hypothetical mission plan for sampling a near-Earth asteroid. It may be some time before such a mission takes flight, but it builds on proven technologies and would be invaluable in assessing the threat and value of comets and asteroids. Indeed, larger versions could be used to protect Earth, not by destroying an asteroid on a collision course, but by producing thrust from the heated spots, which would gently push it away.

© Adrian Mann

INTERVIEW

BIO

Professor Fedor Šimkovic

Nuclear and subnuclear physicist Šimkovic works at the Department of Nuclear Physics and Biophysics at Comenius University in Bratislava. He leads a team of young scientists and doctoral students in studying the fundamental properties of neutrinos – the most widespread elementary particles in the universe. His research covers various scientific fields of atomic physics, nuclear physics, particle physics and astrophysics. Šimkovic is an ESET Science Award laureate, winning the Outstanding Individual Contributor to Slovak Science award in 2020.

© XXXXXXXX

© Linda Kisková Bohušová

FEDOR ŠIMKOVIC

"BILLIONS OF THEM PASS THROUGH US EVERY SECOND"

The nuclear physicist and ESET Science Award laureate reveals what tantalising information neutrinos can tell us about the cosmos

Interviewed by Daisy Dobrijevic

You study neutrinos. Could you explain what they are?
Neutrinos are one of the most abundant fundamental particles in the universe. They come in three types, or flavours: electron neutrinos, muon neutrinos and tau neutrinos. A neutrino is similar to an electron but has no electrical charge and a tiny mass. Neutrinos are not part of an atom, unlike protons, neutrons and electrons. Like other constituents of the Standard Model of particle physics, they are assumed to be point-like objects – they aren't made of any smaller pieces that we know of.

According to the Standard Model, there exist 12 fundamental particles, namely three families of leptons – electron, muon and tau and corresponding neutrinos – up quarks and down quarks and their antimatter versions. The most abundant are neutrinos, created in the universe's first second just after the Big Bang. Theory predicts that there are 340 Big Bang neutrinos in every cubic centimetre in the universe. Due to very low energy, they have not been experimentally confirmed yet. They form a cosmic neutrino background with a very low temperature of about -271 degrees Celsius [-455 degrees Fahrenheit].

Wolfgang Pauli postulated neutrinos to save the laws of conservation of energy and angular momentum 91 years ago. That they exist in nature was confirmed experimentally only 26 years later. Nowadays, neutrinos remain a mystery for physicists.

Why are neutrinos so difficult to detect?
Neutrinos are elusive subatomic particles that rarely interact with anything. Of the four fundamental forces in the universe, they do not interact through the two strongest of them, namely the strong nuclear force, which holds an atomic nucleus together, nor through the electromagnetic force, which requires the presence of an electric charge and binds electrons in an atom.

Neutrinos possess no electrical charge and interact through the weak nuclear force responsible for the radioactive decay of atoms and significantly weaker gravitational force, whose interaction is even suppressed further due to the tiny mass of neutrinos compared to the standards of subatomic particles.

They stream through most matter as light rays go through a transparent window. Billions of them pass through us every second, mostly coming from the Sun, though we won't feel it. We detect them only indirectly via different modes of weak interactions with matter: neutral interactions channel, in which a neutrino transfers some of its momentum to another particle, and then that particle is detected, or the charged interactions channel in which a high-energy neutrino is transformed into an electron, muon or tau, and these are easily detected. But again, the main problem is that these reactions happen only rarely. Neutrino detectors are primarily located deep underground or underwater to suppress background processes, mostly those with an origin in cosmic rays.

What can studying neutrinos tell us about the universe?

INTERVIEW

© Alamy

© NASA/ESA

Above: Supernovae are a source of neutrinos. This shows SN 1987A within the Large Magellanic Cloud

Left: Blazars are another confirmed source of neutrinos

NEUTRINOS ARE ELUSIVE PARTICLES THAT RARELY INTERACT WITH ANYTHING

Humankind has studied the universe for thousands of years by looking with the naked eye at the fascinating night sky full of stars and planets. Starting with the previous century, electromagnetic radiation of different wavelengths, such as radio waves, infrared light, X-rays and gamma rays, was exploited to open additional windows to the universe.

Today, scientists are starting to open a completely new window to the universe by means of neutrinos that deliver information about its make-up and the history of the stars and galaxies. This new field, called neutrino astronomy, will hopefully reveal new unknown phenomena and help us answer several of the questions we have today.

We don't know why in our universe, matter dominates over antimatter, which we practically do not observe. If the same amount of matter and antimatter had formed at the beginning of the Big Bang, they should have annihilated each other a long time ago and transformed into energy. We do not observe the processes of annihilation of matter and antimatter in the universe. If we want to make an omelette, we have to break an egg. If we want to create a world, we must break the symmetry. Due to hypothetical heavy neutrinos, disruption of charge and spatial symmetry may be responsible for the current balance of matter and antimatter.

Where do neutrinos come from?

So far, three sources of extraterrestrial neutrinos have been observed. The first source is the Sun. The stars, including the Sun, shine because of the nuclear fusion reactions that produce atomic nuclei, including the carbon, nitrogen and oxygen of which we are composed. Low-energy neutrinos, whose production is an accompanying phenomenon of fusion reactions, are practically the only direct probe of the deep interior of the Sun.

In 1987 the second source of extraterrestrial neutrinos was observed for ten seconds when a star in the Large Magellanic Cloud exploded as a supernova, SN 1987A. A few hours before the arrival of the light, low-energy neutrinos from SN 1987A reached Earth after a journey of 170,000 light years. About 25 were registered in detectors in three underground laboratories. They confirmed the theory of how stars explode to create the majority of the elements in the periodic table.

Neutrino astronomy wants to identify the sources of this radiation through high-energy neutrinos, locate point sources of neutrinos from the centre of our galaxy or outside and understand the related processes. We can get important information about all this by registering high-energy neutrinos in neutrino telescopes built or under construction in the South Pole's ice, the Mediterranean sea or Lake Baikal. Blazars, associated with a supermassive black hole at the centre of an active galaxy, are the third confirmed source of extraterrestrial neutrinos.

There's growing interest in geoneutrinos. Most are electron antineutrinos originating in beta decay branches of potassium-40, thorium-232 and uranium-238, radionuclides naturally occurring in the Earth. These decay chains account for more than 99 per cent of the present-day radiogenic heat generated inside the Earth at the level of 30 to 40 terawatts. It's like we have about 40,000 nuclear power plants in operation. Without this heat, we would freeze. Geoneutrinos offer a unique probe of what lies deep below our planet's crust, and their study can give substantial new insights into the interior of Earth. So far, tens of geoneutrino events were registered in detectors in KamLAND and Gran Sasso underground laboratories.

Do neutrinos have applications outside of research? Can we use them for anything?

Neutrinos are poorly understood, so the current priority is basic research. It is sometimes a long-distance run from basic research to application in practice. Although it doesn't seem like it, neutrinos already offer some practical applications. Neutrino physics stimulates the development of particle physics detectors, which can have broader applications.

In 2020, there were 447 nuclear fission power stations in service globally, 55 in construction and 111 in the design process. Due to increasing energy consumption, society must count on this energy source. The primary issue is nuclear reactors' safety and economic operation, thus the complete understanding and control of processes inside nuclear power plants is required. Recently built detectors at nuclear reactors, whose primary task is to confirm or disprove the existence of additional neutrino identities, allow monitoring of the complex processes inside these objects.

Furthermore, it might be possible for the International Atomic Energy Agency to exploit neutrino detectors to control the Treaty on the Non-Proliferation of Nuclear Weapons by countries. In most nuclear reactors, uranium is transformed into plutonium. But in order to actually make a nuclear weapon, the reactor has to be shut down, the plutonium removed and replaced with enriched uranium. In this process, the production of neutrinos is strongly suppressed, and the neutrino detector notes it. There are some considerations that neutrinos could be used for finding minerals and oil deposits, global communication or communication with extraterrestrial life – today's utopia is tomorrow's reality.

What do you hope to achieve with your neutrino research?

Neutrino physics is exciting and full of thrilling discoveries. Neutrinos remain the most mysterious fundamental particles, and we still don't know the answers to several undeniably basic questions. I am a theorist interested in all the processes in which the neutrino is involved. For me, the atomic nucleus is a laboratory for studying the interactions and properties of neutrinos. It's amazing if experimental measurements confirm the theoretical assumptions. My life task is to organise and develop neutrino physics in Slovakia. For that purpose, I established a team of young physicists at Comenius University in Bratislava, working on problems of three prominent neutrino physics experiments. We are trying to unite the neutrino community, especially in Central Europe, and attract young people to neutrino physics.

How does it feel to win the 2020 ESET Science Award for Outstanding Individual Contributor to Slovak Science?

Unrepeatable. Unforgettable. I have never experienced such a feeling, and I keep coming back to it. The moment when the chairman of the ESET Science Award International Jury – the Nobel Prize winner Mr Kip Thorne – said my name is still in front of my eyes. The award symbolically came on the 90th anniversary of the first report about neutrinos in Wolfgang Pauli's letter to Tübingen.

My sincere compliments to those who came up with the idea of these awards, and mainly to ESET for a transparent and high-level organisation of the competition. The success came unexpectedly, and it's even nicer for it. I'm very honoured by the jury's decision. I would not have been sad even if I hadn't won. Failures motivate me for progress. I am also aware that there is nothing more distant than the success from yesterday, but I will be very happy if somebody from my young coworkers or students will be awarded the ESET Science Award prize in the future.

How valuable is the ESET Science Award for highlighting the achievements of Slovak science on the global stage?

I would like to congratulate ESET and the ESET Science Award organisers, who have succeeded in doing something exceptional in Slovakia. I bow my hat in front of ESET, which supports and promotes science, research and education in Slovakia by understanding that the future is in science.

Despite all the pandemic boundaries, there were already three successful editions of the ESET Science Awards with a strong response in Slovakia and the world. I do not doubt that the forthcoming editions will be even more exceptional, with a strong resonance in society. This is the way forward for science in Slovakia. It's an example worth following in other countries.

I was kindly surprised to receive many warm congratulations from friends, colleagues and experts worldwide. One of my collaborators wrote to me: "You already had international recognition, and now you got it locally. Sometimes it is more demanding to get domestic respect."

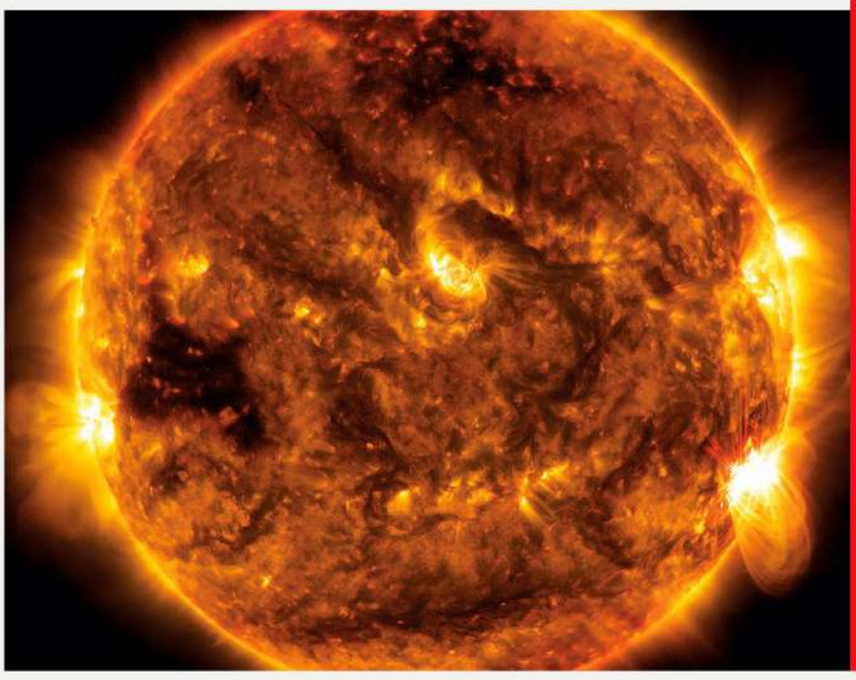
Has your outlook on scientific research changed since winning the award?

Nothing has changed in my scientific plans. I believe that the award will help build our scientific team focused on neutrino physics, attracting more skilled young people to solve current theoretical and experimental tasks in neutrino physics research. The ESET Science Award has changed my view on the role of science in society and the need to contribute to making it better. Science is long-distance running, and its importance is not well understood. It often produces results that are not clear enough. But it turns out that the desired knowledge and outputs will come over time.

In order to become a country of knowledge, it is essential to prepare society for the significant changes that are sure to come. The labour market structure will be changed with the introductions of robotics, modern technologies, bioengineering and artificial intelligence. Climate change is approaching. In solving the related tasks and challenges, the potential for science is enormous.

Maybe the time when Earth's resources will not be sufficient for world society is not far away. If humanity wants to survive and develop, it must find new existential resources and ways to use them, thus there is an urgent need to colonise nearby cosmic space, first robotically. Humanity needs the courage to step into the unknown. In addition, we have to understand the universe itself and the processes inside it. It might be that neutrino physics will help us receive and identify signals from other civilisations. As Enrico Fermi said: "Where the hell are the other Earths?" We are at the beginning of the road, and it's hard to predict where it goes.

Right: Low-energy neutrinos are produced in the Sun during nuclear fusion



© NASA

NEW ATOMIC CLOCK LOSES JUST ONE SECOND EVERY 300 BILLION YEARS

The device could help hunt dark matter or search for gravitational waves

Reported by Elizabeth Howell

1 IRIDIUM NEXT SATELLITE
A demonstration unit of the Deep Space Atomic Clock (DSAC) was hosted on board an Iridium NEXT satellite, the second generation of satellites for the Iridium satellite phone system.

2 SMALL-SCALE
A fraction of the size of its lab-based counterparts, the DSAC was just 0.0056 cubic metres (0.2 cubic feet) – smaller, lighter and more stable than any other atomic clock in space.

3 SIGNAL COMPARISON
Ground stations around the world took measurements of the speed and position of the same GPS satellites and compared them to the DSAC.

4 TITANIUM VACUUM CASE
The DSAC was housed inside a vacuum case made of titanium; this provided a very strong and light enclosure to protect the delicate inner workings.

5 GPS SATELLITES
The DSAC mission used the constellation of GPS satellites that already transmit timing data to test its performance in orbit.

6 WAVEGUIDE WINDOW
This was the point where the microwave signal was beamed in to measure the oscillations of the mercury atoms.

7 MULTIPOLE TRAP
There were two sections: the multipole trap was where the mercury atoms were tested by the microwave signal, which went to control the quartz clock.

8 QUADRUPOLE TRAP
Atoms were trapped in the DSAC by electric fields generated by the rods visible inside the case; the quadrupole trap had only four strip conductors to provide a clear path from the windows.

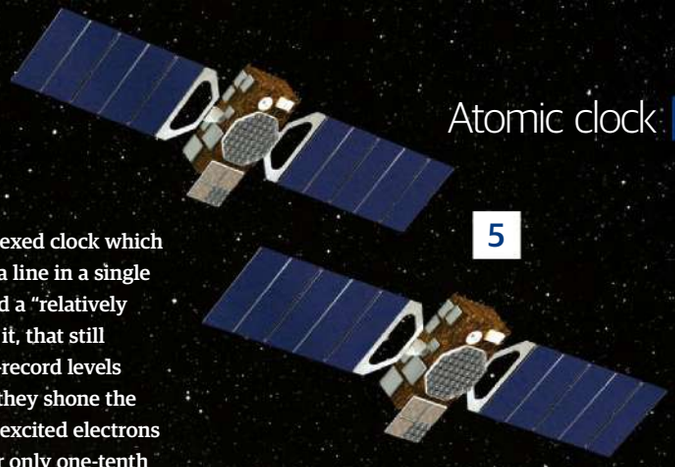
A new high-performance atomic clock will measure time so precisely that it will only lose one second every 300 billion years, allowing for more exact measurements of gravitational waves, dark matter and other phenomena. "Optical lattice clocks are already the best clocks in the world, and here we get a level of performance that no one has seen before," said Shimon Kolkowitz, a University of Wisconsin-Madison professor. "We're working to improve performance and to develop emerging applications that are enabled by this improved performance."

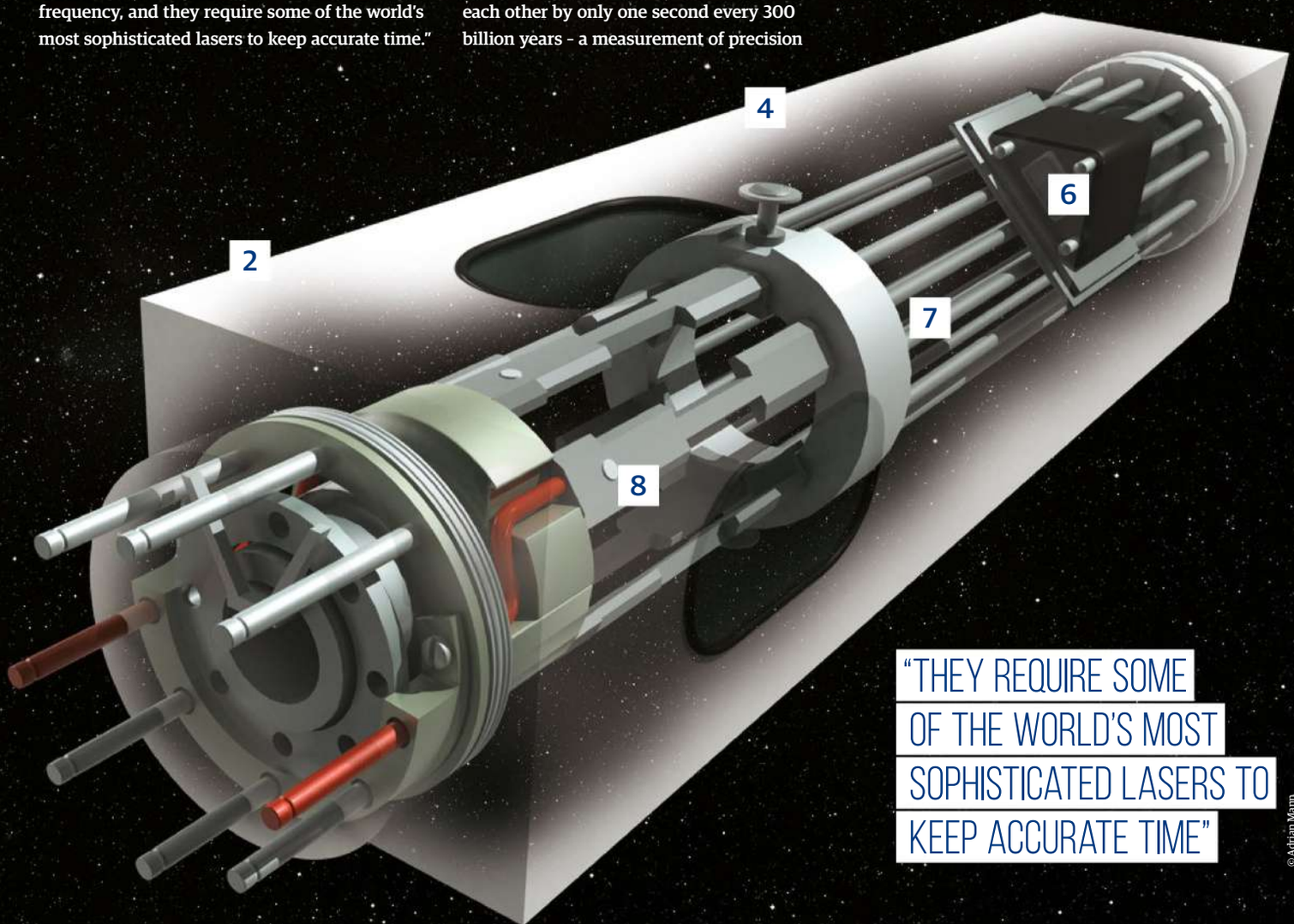
Atomic clocks track the resonances of atom frequencies, usually caesium or rubidium. This process allows such clocks to measure time with a high degree of accuracy. NASA's Deep Space Atomic Clock was a space-based experiment which tested the technology in orbit for two years. Atomic clocks work by tracking the energy levels of electrons. "When an electron changes energy levels, it absorbs or emits light with a frequency that is identical for all atoms of a particular element," researchers explained in a statement. "Optical atomic clocks keep time by using a laser that is tuned to precisely match this frequency, and they require some of the world's most sophisticated lasers to keep accurate time."

A new study created a multiplexed clock which separated strontium atoms into a line in a single vacuum chamber. The team used a "relatively lousy laser," as Kolkowitz called it, that still managed to produce near-world-record levels of precision in measurement. If they shone the laser on a single clock, the laser excited electrons in the same number of atoms for only one-tenth of a second. But with two clocks at the same time, the atoms stayed excited for 26 seconds. "Normally, our laser would limit the performance of these clocks," Kolkowitz said. "But because the clocks are in the same environment and experience the exact same laser light, the effect of the laser drops out completely."

The group then attempted to measure differences between clocks precisely, because two groups of atoms in slightly different environments will 'tick' at different rates due to changes in magnetic fields or gravity. The team ran the experiment over 1,000 times to measure the difference, finding more precision in that measurement over time. Ultimately, the researchers detected a difference in the ticking rate between two atomic clocks "that would correspond to them disagreeing with each other by only one second every 300 billion years – a measurement of precision timekeeping that sets a world record for two spatially separated clocks."

Coincidentally, an unrelated study revealed a difference between the top and bottom of a dispersed cloud of atoms about ten times better than the UW-Madison group. This study, led by Colorado research institute JILA, formerly known as the Joint Institute for Laboratory Astrophysics, set the world record overall for the most precise frequency difference. The UW-Madison group comes in second. "The amazing thing is that we demonstrated similar performance as the JILA group despite the fact that we're using an orders-of-magnitude worse laser," Kolkowitz said. "That's really significant for a lot of real-world applications, where our laser looks a lot more like what you would take out into the field."





"THEY REQUIRE SOME OF THE WORLD'S MOST SOPHISTICATED LASERS TO KEEP ACCURATE TIME"

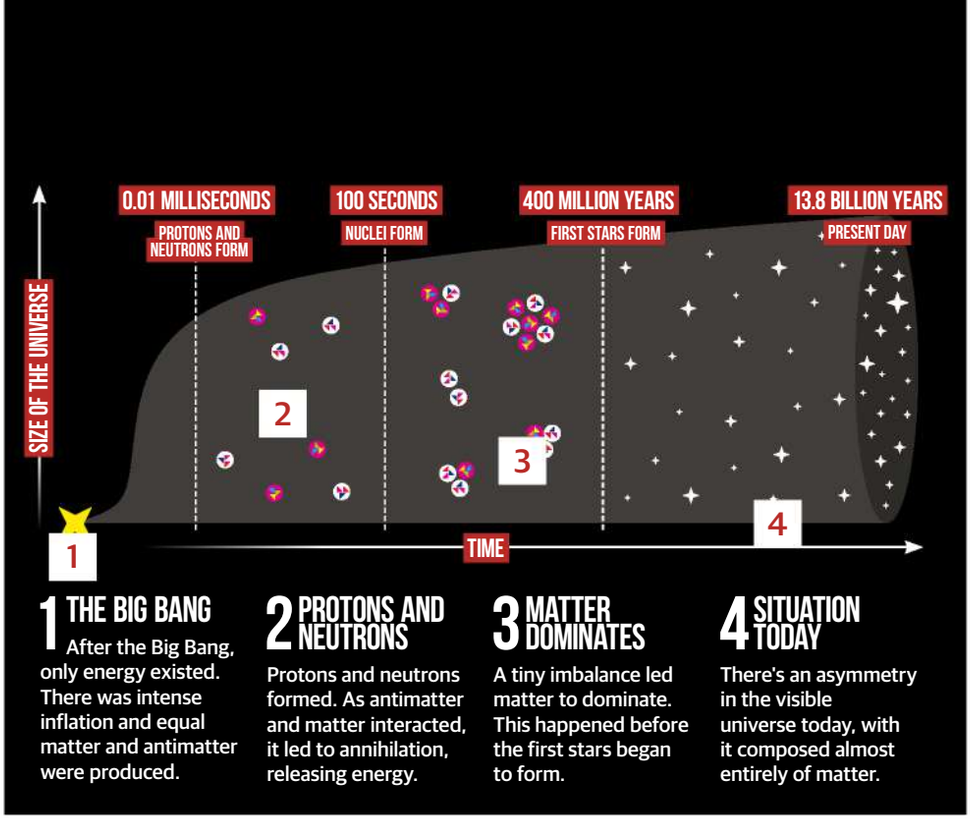
© Adrian Mann

GREATEST SPACE MYSTERIES

THE TRUTH IS OUT THERE, ACCORDING TO ASTROPHYSICISTS, PLANETARY SCIENTISTS AND ASTRONOMERS

Interviewed by David Crookes

©Getty


0.01 MILLISECONDS
PROTONS AND NEUTRONS FORM
100 SECONDS
NUCLEI FORM
400 MILLION YEARS
FIRST STARS FORM
13.8 BILLION YEARS
PRESENT DAY
SIZE OF THE UNIVERSE
TIME
1
2
3
4
1 THE BIG BANG
After the Big Bang, only energy existed. There was intense inflation and equal matter and antimatter were produced.
2 PROTONS AND NEUTRONS
Protons and neutrons formed. As antimatter and matter interacted, it led to annihilation, releasing energy.
3 MATTER DOMINATES
A tiny imbalance led matter to dominate. This happened before the first stars began to form.
4 SITUATION TODAY
There's an asymmetry in the visible universe today, with it composed almost entirely of matter.

WHERE DID THE ANTIMATTER GO?

It was destroyed after the Big Bang

Antimatter and matter are supposed to be created in comparable abundance. However, almost all matter observed from Earth seems to be made of matter rather than antimatter. Where did the antimatter go? Antimatter was either destroyed within a second after its creation in the Big Bang, or the Big Bang made antimatter in a distant universe that is far beyond our reach and our visible world happens to be in a matter zone. The first possibility could be caused by a possible tiny asymmetry between matter and antimatter, and it is being studied by accelerator experiments. The second possibility is being explored by balloon and space-based experiments – a recent famous one is the AMS-02 experiment mounted on the International Space Station. In those experiments, scientists are looking for tiny fragments of primordial antimatter in cosmic rays.

Dr Aihong Tang, ***Brookhaven National Laboratory, New York***

© Adrian Mann

WHY DO CRAFT SPEED UP NEAR EARTH?

It may be due to Earth's spin

Possible effects include the atmospheric drag of low-orbit trajectories, ocean and solid tides, charging and magnetic momentum of craft by solar wind, overlooked general relativity phenomena or thermal radiation. Or perhaps it's a strange dark matter halo around Earth. Also perplexing is the phenomena's disappearance in flybys since 2005.

Dr Luis Rodríguez ***Universidad de Extremadura, Spain***

CAN LIGHT ESCAPE BLACK HOLES?

Theory says that it can

Black holes have been found in vast numbers, sitting at the cores of pretty much every large galaxy that's been studied in detail. The holy grail of observational research in this field is to obtain an 'image' of the immediate surroundings of a black hole to observe the flows of matter around it, one of the goals of the Event Horizon Telescope. Theory tells us that nothing can escape from the event horizon of a black hole - not even light. This is how a black hole is characterised. However, theory also tells us that indirect exchange of energy can make the event horizon glow in a process first proposed by Stephen Hawking. Finding evidence of such glowing black hole horizons will be an important discovery. As telescopes become more powerful across the full spectrum of energies, from radio waves to gamma rays, we aim to probe ever closer to black holes in the universe. Who knows what we may find.

Dr Poshak Gandhi, *University of Southampton, UK*

© Tobias Roetsch

WHAT IS DARK ENERGY?

Robert Caldwell, ***Dartmouth College, New Hampshire***

The accelerated expansion of the universe is thought to be driven by a dark force that comprises around 75 per cent of the energy of the cosmos and possesses a strong, gravitationally 'repulsive' tension. It appears to resemble a cosmological constant – a perfect sea of constant, uniform energy and tension – but further measurements are needed.

WHAT CLEARED THE UNIVERSE'S FOG?

Dr Varoujan Gorjian, *Jet Propulsion Laboratory*

Stars and galaxies are the prime candidates here, but it's a type of galaxy called 'starburst galaxies' that play a major role. Starburst galaxies have a higher rate of supernovae explosions and eruptions than a galaxy like the Milky Way. Such eruptions blow holes in a galaxy, from which the ionising radiation can escape out and reionise the entire universe. Massive stars in galaxies produce ionising radiation, which then leaks out of galaxies and reionises the universe.

WHERE DO COSMIC RAYS COME FROM?

Mostly from exploding stars

Cosmic rays are charged particles travelling near the speed of light from outside the Solar System, but some come from our Sun. They're mostly made up of the nuclei of atoms – from the lightest elements of hydrogen and helium to the heaviest elements of iron and uranium. A small fraction are made of electrons and subatomic particles, and there are a few particles of antimatter: positrons and antiprotons.

Cosmic ray particles are generated by supernovae explosions within our galaxy, with a small amount coming from solar flares and activity on our Sun. Since these particles are charged, the magnetic field of the galaxy redirects cosmic rays so that Earth is bombarded by these particles. Luckily, our magnetic field and atmosphere protect us.

Dr Varoujan Gorjian, *Jet Propulsion Laboratory*

WHAT CAUSES GRAVITY?

We think it may be caused by a particle called a graviton

Gravity is the ultimate force of attraction throughout the universe. Everything with mass has gravity, including stars, planets and even people. The pull of an object's gravity gets stronger as you get closer, and its strength is proportional to the object's mass. Something as big as Earth has enough gravity to keep us pulled down to its surface, and the Sun has enough gravity to keep Earth orbiting around it. The mathematics of gravity were first described by Isaac Newton in the 17th century, while Albert Einstein, about 100 years ago, showed how gravitation could be better understood as a warping of space and time.

Dr Robert Hurt, *California Institute of Technology*

WHAT WAS THE WOW! SIGNAL?

Robert H. Gray, *Author of The Elusive Wow: Searching for Extraterrestrial Intelligence*

It's one of the best candidates for a radio signal from the stars – detected in 1977, it was there for a minute, then gone. It may have been interference, but it could have been something we need to listen to for longer to detect it again.

© Alamy

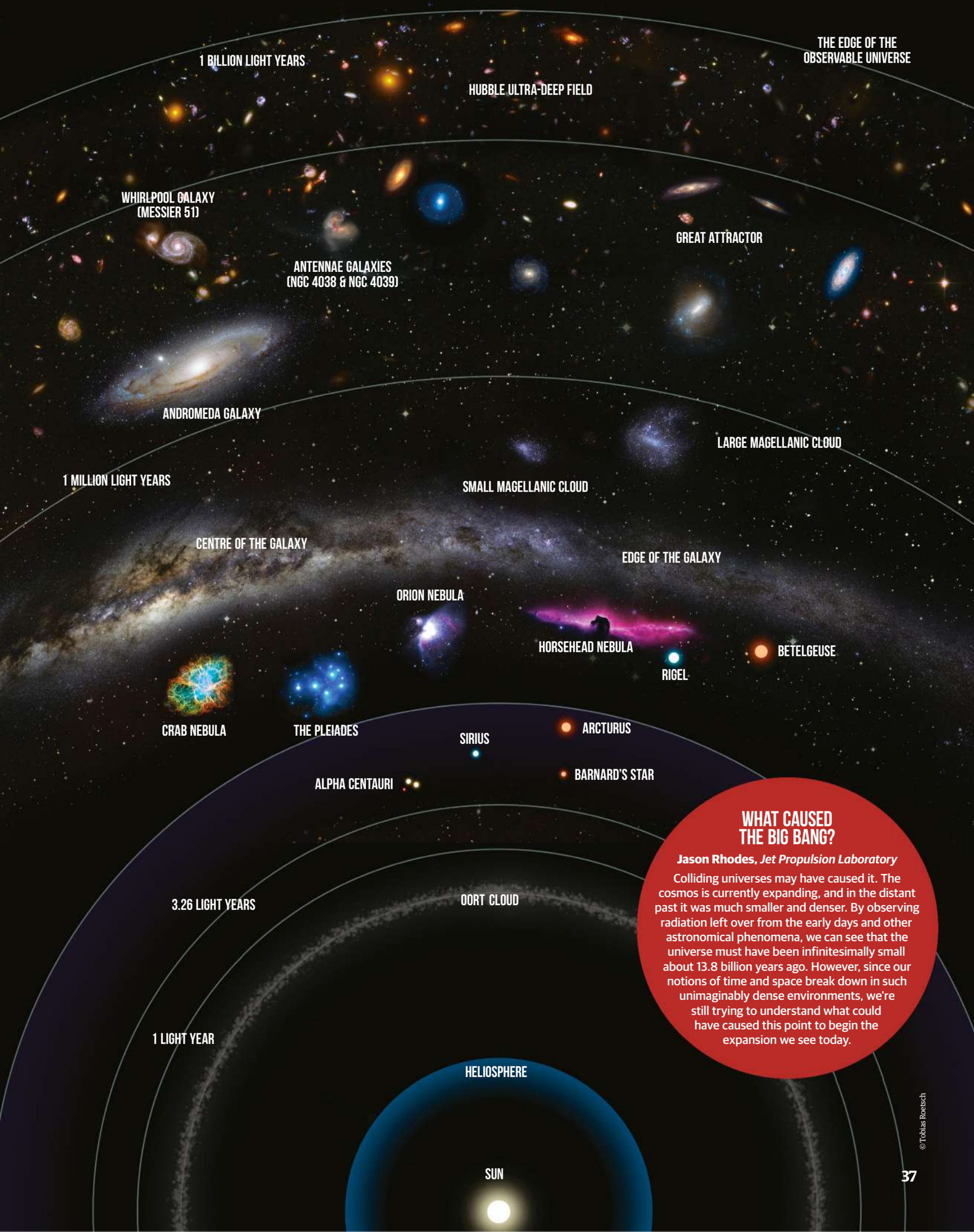
HOW BIG IS THE UNIVERSE?

At least 420 trillion cubic light years

Determining the size of the universe is very tricky due to the fact that the main method we have for exploring the universe is light. As light has a finite speed limit, it takes some time to get from one place to another. While this speed is incredibly fast, the universe is also incredibly large; light from some of the most distant galaxies takes an incredible 13.8 billion years to reach us. Given the speed limit of light, there are parts of the universe that are so far away that light has not had long enough to reach us over the entire history of the universe. The volume within this distance is called the 'observable universe', which has a radius of 46.5 billion light years.

The size of the universe outside this is unknown, as we cannot see it, but estimates suggest it's 250 times the size of the observable universe at a staggering 420,000,000,000,000 cubic light years!

Dr Luke Davies, *University of Western Australia, Perth*



WHAT CAUSED THE BIG BANG?

Jason Rhodes, ***Jet Propulsion Laboratory***

Colliding universes may have caused it. The cosmos is currently expanding, and in the distant past it was much smaller and denser. By observing radiation left over from the early days and other astronomical phenomena, we can see that the universe must have been infinitesimally small about 13.8 billion years ago. However, since our notions of time and space break down in such unimaginably dense environments, we're still trying to understand what could have caused this point to begin the expansion we see today.

©Tobias Roetsch

© Getty

HOW DID SATURN GET ITS RINGS?

Icy moons were ripped apart

Imagine two ring particles – little chunks of ice – in contact with each other near Saturn. The planet's gravitational attraction is a little stronger on the particle closer to Saturn. This difference is called a tidal force and is closely related to the tides in the oceans. Because of tidal forces, it's difficult or impossible for a moon to form very close to a planet.

Saturn's rings are probably the remnants of a large icy body that formed elsewhere and was ripped apart when it came too close to Saturn. In one scenario, a moon like Titan spiralled in through the disc of gas and dust that surrounded the young Saturn. The moon's icy shell could have been torn off, with the fragments going into orbit around Saturn and the moon's rocky core being swallowed by the planet. The icy chunks would have collided and spread, with the particles close to Saturn becoming the ring system and those that moved farther out coagulating into moons.

In another model, a large centaur – a body that escaped the Kuiper Belt – was torn apart by Saturn's tidal forces during a very close chance passage. And in a third concept, a moon of Saturn was destroyed by a comet impact. As in the first model, the fragments in these scenarios would have collided and formed rings and moons around Saturn. Though Cassini has vastly expanded our understanding of Saturn's rings, we still don't know which idea is correct.

Dr Luke Dones, ***Southwest Research Institute, Texas***

WHAT'S CAUSING TABBY'S STAR TO ACT SO WEIRD?

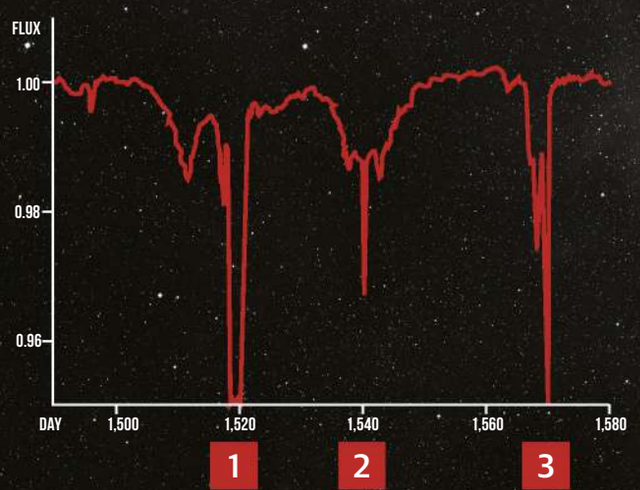
A cool disc may be blocking out its light

We've observed stars that dim in brightness for a few days like this star, but they are all very young and have giant discs of gas and dust around them. In those cases, we know the disc is coming between us and the star, blocking the light. As far as we can tell, Tabby's Star (KIC 8462852) isn't young and it doesn't have a big disc around it. It's possible that there's a small, cool disc in a wide orbit far away from the star, or that there's a cloud of gas in the interstellar medium, the space between stars, that's passing along our line of sight and blocking the light. For both of these scenarios, we have predictions for what the light would look like at different wavelengths during another big dip. Now we are waiting patiently for another dip, and will record data as soon as we see one to test both of these hypotheses.

Dr Ben Montet, ***University of New South Wales, Sydney***

LIGHT CURVE OF TABBY'S STAR

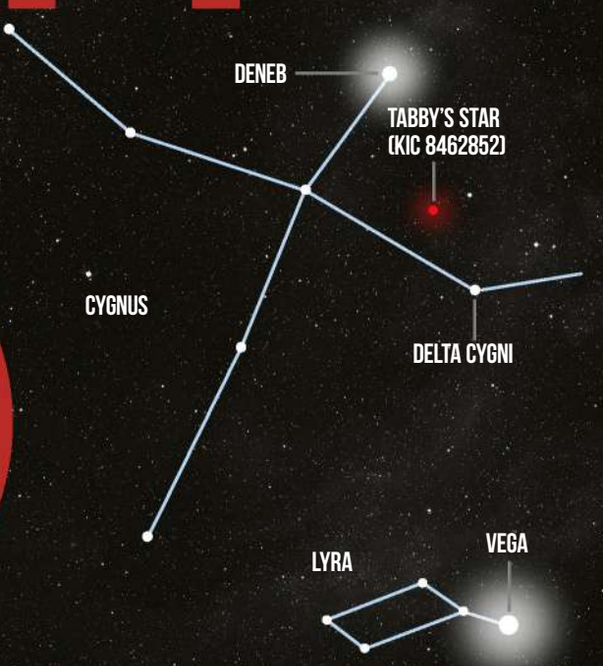
Tabby's Star exhibits unusual behaviour when astronomers look at its light curve



1 DAY 1,520
You can see here that the light from Tabby's Star dimmed on day 1,520 of Kepler's mission.

2 DAY 1,540
Here we see a triple dip in flux with a symmetric profile – a pattern that's seen in other parts of the light curve for Tabby's Star.

3 DAY 1,570
Just 50 days later, a dip of a similar shape but different magnitude occurred. Was it caused by two different planets moving in front of the star?



WHAT ACCOUNTS FOR THE KUIPER CLIFF?

Dr Olivier Hainaut, ***European Southern Observatory***

The Kuiper Belt is believed to be what is left of the outskirts of the protoplanetary disc from which the Solar System was born. The small number of objects still present in the inner belt shows that most of the objects were ejected, possibly due to the outward migration of Neptune. This should have left the outer belt intact, but the number of objects beyond 45 AU is virtually zero – called the Kuiper cliff.

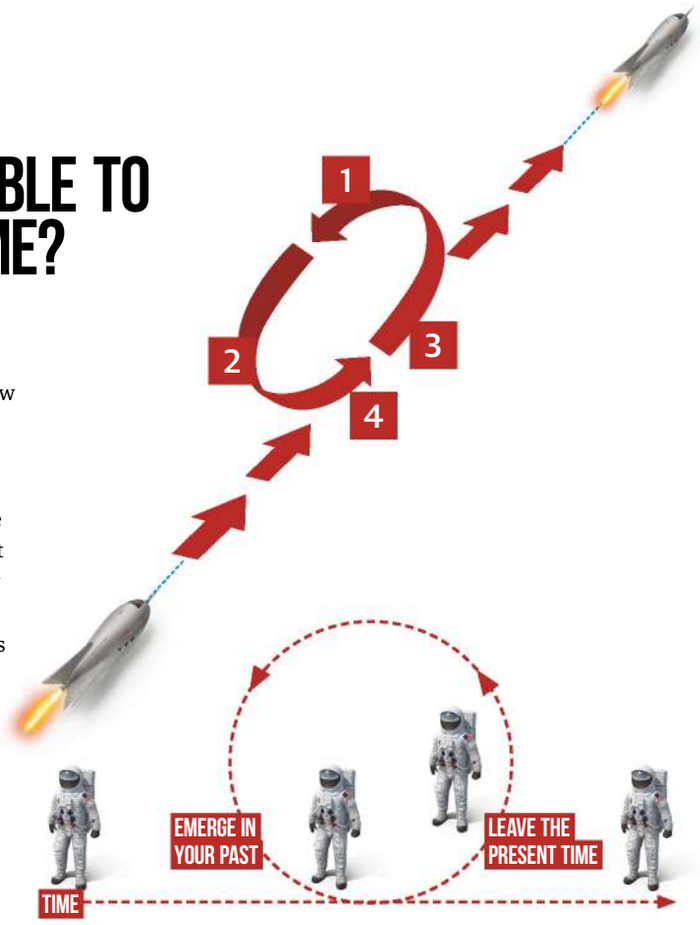
WILL WE EVER BE ABLE TO TRAVEL BACK IN TIME?

Theoretically, yes

Einstein's theory of general relativity has some solutions that are sufficiently twisted so as to allow time travel to the past, such as wormholes and moving cosmic strings. Just as Magellan's crew went west around the world and arrived back in Europe, a time traveller can go towards the future and circle back through curved space-time to visit their past. If you built a time machine in 3000 by twisting space-time, you could go from 3002 to 3001, but you couldn't go back to 2016 as that was before it was built.

To know whether these machines could be created, we'll need to learn the laws of quantum gravity – how gravity behaves on microscopic scales. It's why physicists find the possibilities of time travel so interesting.

Professor J. Richard Gott, ***Princeton University, New Jersey***



1 SPACE-TIME

For it to work, an object needs to follow a world line through space-time that returns it to the same coordinates that it was at before it set off.

2 TIME TRAVEL LOOP

A closed timelike curve is a time travel loop. Einstein said this would create a paradox – such as going back and killing your father before your birth.

3 BLACK HOLES

A spinning black hole would create a powerful gravitational field that could warp the fabric of existence and loop space-time on itself.

4 QUANTUM MECHANICS

But quantum mechanics suggests small objects – perhaps matter or information – could enter a closed timelike curve without a paradox.

WHY IS THE SUN'S OUTER LAYER SO HOT?

Chloe Pugh, ***University of Warwick***

The Sun's outer atmosphere is over 1 million degrees Celsius (1.8 million degrees Fahrenheit), while the surface is just 5,499 degrees Celsius (9,930 degrees Fahrenheit). Magnetic reconnections, which cause solar flares and coronal mass ejections, or magnetohydrodynamic waves could be transporting the energy, though it's likely to be both or something undiscovered.

DO WHITE HOLES EXIST?

It's certainly possible

Black holes are like gravitational quicksand: they pull things towards them in the same way all matter does, appearing to be nothing special. But when you come too close, the collected stuff has bent space and time so much that there's no escape. If you can imagine the opposite of quicksand, soil that lets nothing in but can emit what it contains, you're imagining a white hole. They also gravitationally attract, but things only come out. The existence of black holes was once doubted, but they are more abundant and varied than ever thought. The greatest mystery may even tie black and white holes together: how do they die? Black holes could die by quantum mechanically metamorphosing into symmetrically exploding white holes, and seeking signs of these explosions could confirm if white holes exist.

Professor Hal Haggard, *Bard College, New York*

©Tobias Roetsch

WHY IS JUPITER'S GREAT RED SPOT SO LONG-LASTING?

There's no land on the gas giant to break it apart

Jupiter is a gaseous planet with rapid rotation, which causes the winds to organise into bands of easterly and westerly winds, but this also causes turbulence. Vortices (cyclones and anticyclones) are a natural feature of this kind of turbulent air flow; the Great Red Spot (GRS) is an anticyclone, spinning counterclockwise in the southern hemisphere. It's more stable than an anticyclone on Earth as there are fewer disruptions, like land masses, to break it apart. It's also confined by strong winds to not move in latitude, making it even more stable. In essence, it's a storm rolling like a ball bearing in a moving channel of winds.

Dr Amy Simon, *Goddard Space Flight Center*

1979 The first clear close-up image of the GRS was taken by Voyager 1

22° The GRS is 22 degrees south of Jupiter's equator

20,000KM The length of Jupiter's GRS, equal to 12,400 miles

400 Minimum number of years that the storm is believed to have lasted

SIX Earth days for the GRS to rotate counterclockwise

680KM/H Speed of the winds on the oval edges

© NASA/JPL-Caltech

WHY DO PULSARS PULSE?

Dr Rainer Kresken, *European Space Agency*

Pulsars are tiny, fast-spinning, very dense objects that have very strong magnetic fields. Like lighthouses, these rotating fields can direct periodic electromagnetic pulses towards Earth, where they can be detected with radio antennae.

HOW WOULD WE RECOGNISE OTHER LIFE IN THE UNIVERSE?

We'd detect 'alien-made' signals

Even if primitive life were ubiquitous, 'advanced' life may not be, as our emergence on Earth may have depended on many contingencies, such as the phases of glaciation, the planet's tectonic history and the presence of the Moon. But Search for Extraterrestrial Intelligence (SETI) research is surely worthwhile.

We are searching for non-natural radio transmissions from nearby and distant stars, the plane of the Milky Way, the galactic centre and from nearby galaxies. But even if the search succeeded, it's unlikely that the 'signal' would be a decodable message. A radio engineer familiar with amplitude modulation might have a hard time decoding modern wireless communications. Indeed, compression techniques aim to make the signal as close to noise as possible – insofar as a signal is predictable, there's scope for more compression. Then again, many think 'organic' intelligence is a brief interlude before the machines take over, so if we were to detect life, it's more likely that it would be inorganic.

Martin Rees, *Astronomer Royal, UK*

© NRAO

Spring Sale

5 ISSUES FOR £5/$5/€5*

BIG SAVINGS ON OUR BEST-SELLING MAGAZINES

WIN
Dakar 2022's extreme DESERT RACERS
HOW IT WORKS
WHY WE LOOK FOR WATER ON MARS
See inside a QUANTUM COMPUTER
ON BOARD A CREWLESS CARGO SHIP
HEAT PUMPS EXPLAINED
WORLD'S BIGGEST LASER
DISCOVER THE ALL-POWERFUL DEVICE THAT'S SOLVING MANY OF THE PLANET'S PROBLEMS

SAVE 90%

SAVE 89%

SAVE 88%

SAVE 91%

SAVE 92%

SAVE 90%

SAVE 90%

BRITAIN'S BEST VALUE HOMES MAGAZINE
Style at Home
DIY STORAGE CRAFT DECORATING FOOD GARDENING
ONLY £2.49 BEST VALUE!
IDEAS & ADVICE
LOW-COST REVAMPS
427 STYLE FIXES + SIMPLE UPDATES
50+ SPRING BUYS Home treats
PROJECT FOCUS
BRILL BUDGET BATHROOM UPDATES
HOW TO TILE A SPLASHBACK
SMART PAINT IDEAS FOR BEDROOMS

SAVE 77%

See the entire range online at

www.magazinesdirect.com/spring22

or phone **0330 333 1113** and quote code **SP22**

*Offer closes 31st April 2022. Offer open to new subscribers only. After your trial issues, your subscription will continue at the price shown at the point of purchase. Saving is based on full subscription rate. We will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue (up to eight weeks overseas). If the magazine ordered changes frequency per annum, we will honour the number of issues paid for, not the term of the subscription. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Selected magazines are available on this introductory offer and exclusions apply. For full terms and conditions, visit www.magazinesdirect.com/terms. For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday-Friday 9am-5pm UK Time (excluding Bank Holidays) or e-mail: help@magazinesdirect.com. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

Focus on

RYUGU SAMPLES REVEAL ASTEROID'S INNER WORKINGS

Pieces of rock from the asteroid Ryugu splashed down on Earth in 2020

Reported by Chelsea Gohd

Ryugu is a near-Earth asteroid that Japan visited with its Hayabusa2 spacecraft. The craft launched in 2014, arrived at the space rock in 2018 and in December 2020 dropped off a capsule carrying 5.4 grams of asteroid material to Earth. This has given scientists the ability to study the asteroid up close here on our home planet with a full range of technologies.

In a new study, scientists reveal a detailed picture of the asteroid and what its surface and subsurface material is really like. As it turns out, Ryugu is covered in flat and elongated pieces. The team used an optical microscope to take images of grains of material from Ryugu. To get an idea of how these samples represent the complete asteroid, the team also compared what they saw in the lab with observations made by the Hayabusa2 spacecraft, which studied the asteroid from orbit for 16 months and captured some incredible close-up imagery of Ryugu during two landing manoeuvres.

© JAXA

"We focused on comparison between pebbles observed by the spacecraft and the returned samples to evaluate the representativeness of returned grains gathered from limited areas of the asteroid," said Shogo Tachibana, a cosmochemist and researcher with the Japan Aerospace Exploration Agency (JAXA) and the University of Tokyo. "The returned samples well represent Ryugu surface particles from a morphological point of view," Tachibana said, adding that the pieces they studied were flat and elongated. "This morphology, probably broken pieces of larger boulders, seems characteristic of Ryugu surface pebbles, and we have them in hand now," Tachibana said.

The process of getting pieces from an asteroid from outer space to Earth and safely into the hands of scientists is tricky, to put it lightly. Tachibana, who worked with the sample collection and capsule recovery teams on the Hayabusa2 mission, said that, unsurprisingly, "there have been many nerve-wracking things. The safe recovery of the capsule and the rapid and safe preparation for the container opening in the curation chamber were actually most nerve-wracking for me. We had to open the container and take out particles as soon as possible."

Hayabusa2 isn't done yet, however. After delivering the capsule to Earth on 5 December 2020, the probe embarked on its first extended mission to another asteroid.

1 NEAR-INFRARED SPECTROMETER

This instrument gained spectroscopic information in the three-micron wavelength, corresponding to near-infrared.

2 THERMAL-INFRARED IMAGER

This viewed Ryugu in the ten-micron wavelength band and was able to determine its surface temperature.

3 ION ENGINE

Improved electric propulsion converts xenon into plasma ions, generating the speeds needed for Hayabusa2 to travel.

4 SAMPLER HORN

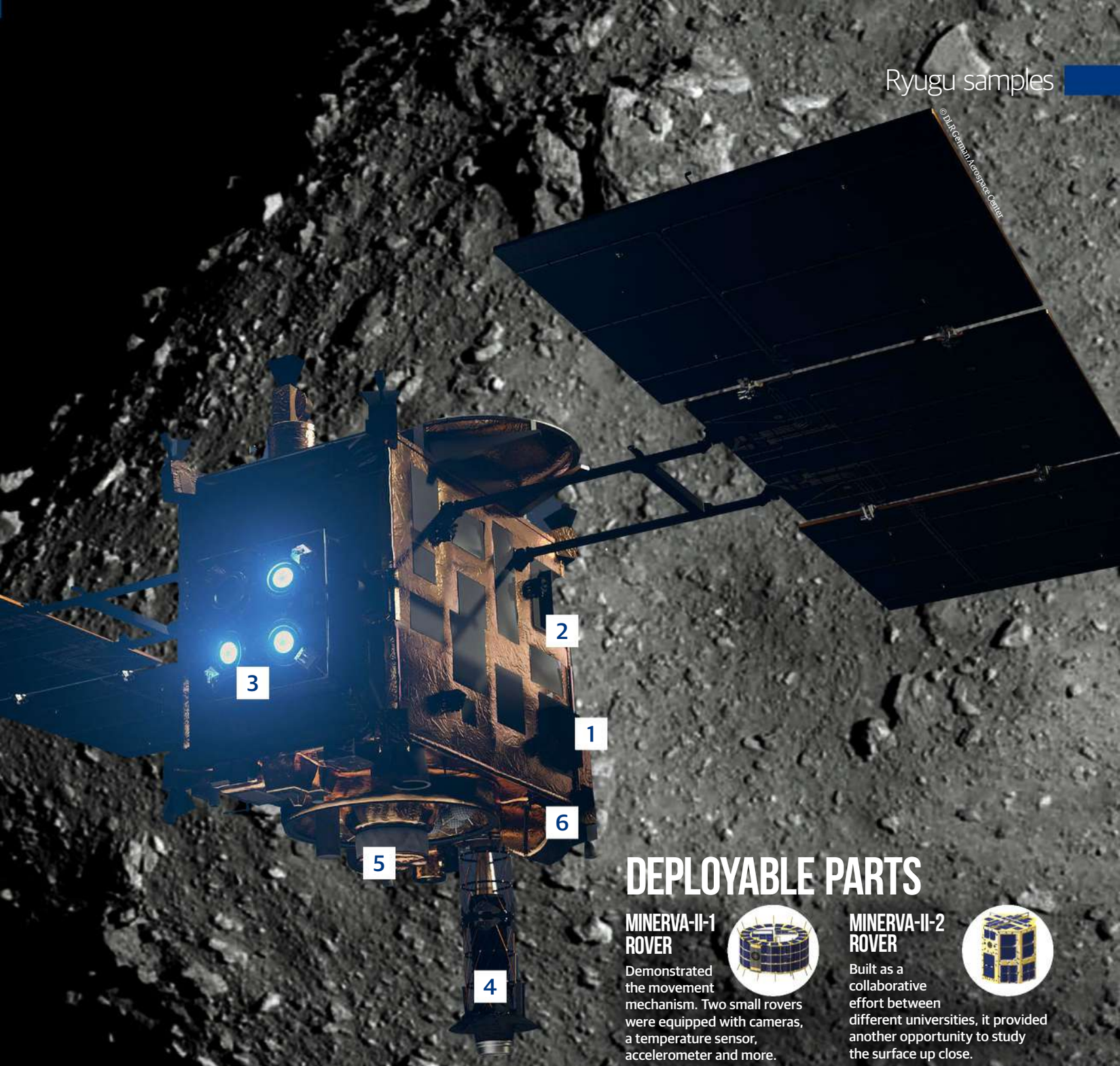
This collected samples from the surface of Ryugu during touchdowns on three occasions.

5 LASER ALTIMETER

This was key in maintaining a certain altitude while acquiring important data about topography, gravity and albedo.

6 OPTICAL NAVIGATION CAMERA WIDE-FIELD

Multiple cameras comprise this instrument, including telescopic and wide-angle cameras which are dedicated to scientific observations and navigation.



DEPLOYABLE PARTS

MINERVA-II-1 ROVER

Demonstrated the movement mechanism. Two small rovers were equipped with cameras, a temperature sensor, accelerometer and more.

MINERVA-II-2 ROVER

Built as a collaborative effort between different universities, it provided another opportunity to study the surface up close.

MASCOT LANDER

MASCOT weighed around ten kilograms and carried four instruments on board. It travelled across the surface by jumping around.

IMPACTOR

The Small Carry-on Impactor (SCI) collided into the surface, revealing internal rock that hasn't been contaminated by space radiation or other environmental effects.

DEPLOYABLE CAMERA 3

DCAM3 imaged the SCI and the asteroid as it impacted the surface to carefully study the whole event and the ejecta released.

RE-ENTRY CAPSULE

This contained the collected samples. Its heatshield was able to withstand temperatures of 3,000 degrees Celsius (5,400 degrees Fahrenheit) to keep the samples intact.

© JAXA

"THE RETURNED SAMPLES WELL REPRESENT RYUGU SURFACE PARTICLES FROM A MORPHOLOGICAL POINT OF VIEW"

SHOGO TACHIBANA

PLANET PROFILE

URANUS

The ice giant that's shrouded in mystery has fascinated explorers for decades

The seventh planet from the Sun, Uranus became the first planet to be found with the aid of a telescope on 13 March 1781 by British astronomer William Herschel. On that fateful night, he described observing a "nebulous star or perhaps a comet". Little did he know that he had just discovered Uranus, which was named after the Greek god of the sky – a name proposed by Johann Elert Bode in 1783.

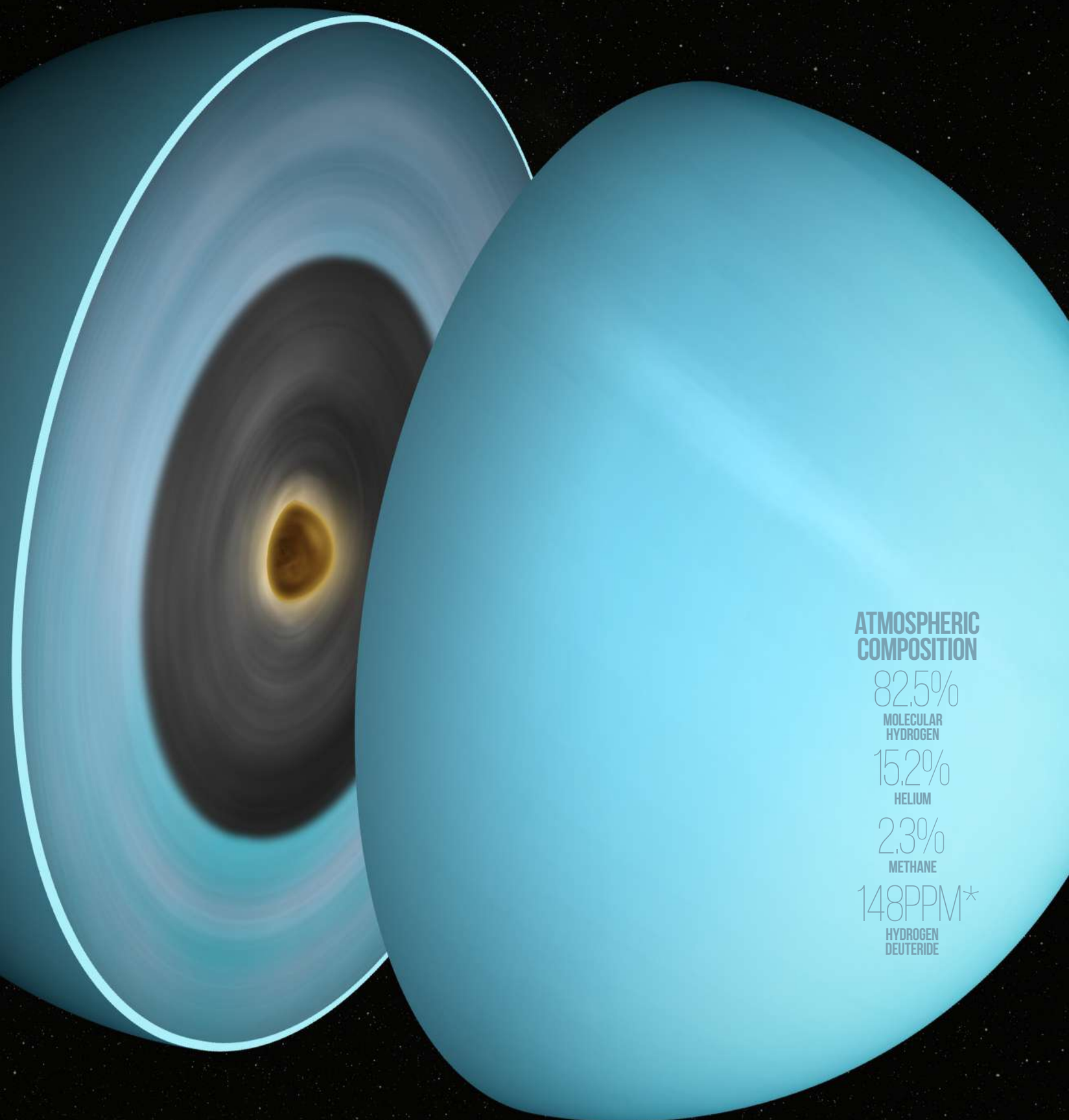
240 years later, Uranus remains a puzzle. What is known is that Uranus is located about 2.9 billion kilometres (1.8 billion miles) from the Sun, about 19 times the distance from Earth to the star, meaning that one orbit of the Sun takes 84 Earth years. The planet is enormous, with a diameter of 50,724 kilometres (31,518 miles) – four times wider than Earth. Uranus has a compositional mass that is 80 per cent a fluid mixture of water, ammonia (NH_3) and methane (CH_4) ices. It's the methane in the outer atmosphere that gives it its blue-green colour, but the thick cloud coverage does not allow our instruments to peer down any further, and is one reason why Uranus remains an enigma.

Astronomers strongly suggest that below the planet's cloud tops is a main atmosphere which contains mostly hydrogen and helium by composition and has traces of methane and other volatiles. Below that is the fluid icy mantle, which makes up most of its composition by mass, but it's also theorised that the pressure and temperatures here are enough to make it 'rain' diamonds at that depth. Finally, at the centre is the silicate iron-nickel core, thought to be between half to just over three times the mass of Earth.

Although there has only been one mission to visit the ice giant close up – Voyager 2 in 1986 – the planet has long been studied by ground and space-based telescopes, such as Hubble and the Keck Observatory in Hawaii. Observations throughout the years have revealed subtle yet surprising details about the pale planet. These include the planet's thin rings, which confirmed that Saturn is not an outlier and rings can form around any planet. Astronomers have also been able to deduce that Uranus' planetary rotational tilt is off by a notable 97.77 degrees, which implies there was a collision in its early age that knocked it over.

Similar to the larger gas giants, Jupiter and Saturn, storms have been observed brewing in the cloud tops of Uranus. In November 2014 the planet was extremely active; storms raged on Uranus that were even observed by amateur astronomers. These observations caused another dilemma in regards to Uranus. As there seems to be no internal heat source and it's a huge distance from the Sun's heat, astronomers question what's going on inside Uranus to make such storms arise. "The colours and morphology of this cloud complex suggest that the storm may be tied to a vortex in the deeper atmosphere similar to two large cloud complexes seen during the equinox," said Larry Sromovsky, a planetary scientist at the University of Wisconsin-Madison, at the time of its discovery.

"OBSERVATIONS THROUGHOUT THE YEARS HAVE REVEALED SUBTLE YET SURPRISING DETAILS ABOUT THE PLANET"



ATMOSPHERIC COMPOSITION

82.5%
MOLECULAR HYDROGEN

15.2%
HELIUM

2.3%
METHANE

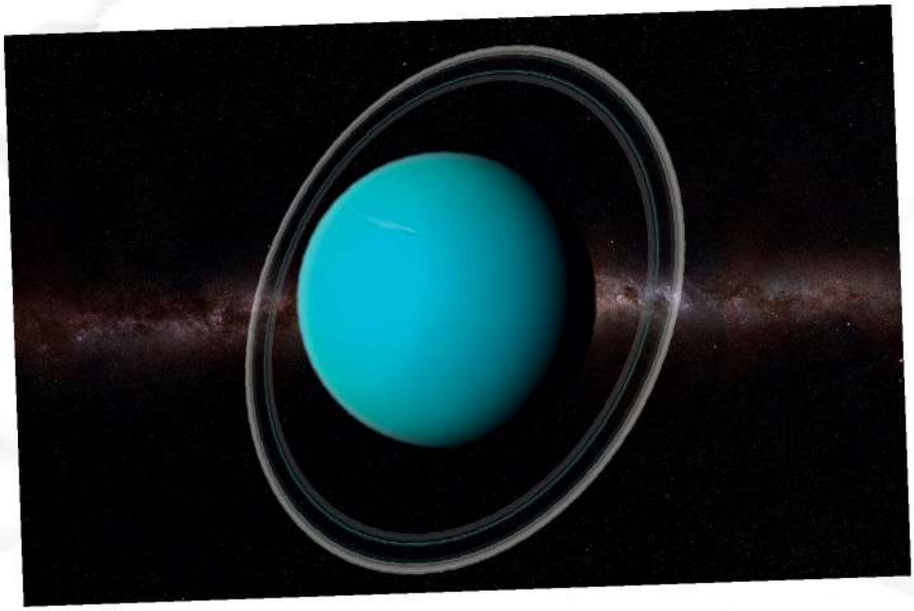
148PPM*
HYDROGEN DEUTERIDE

*PARTS PER MILLION

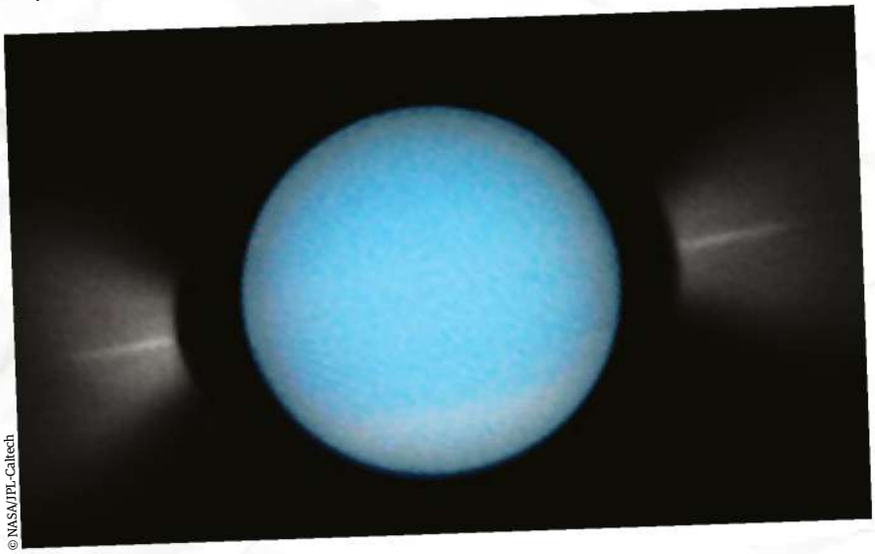
URANUS IN THE NEWS

KNOCKING URANUS ABOUT

Astronomers at Durham University have completed multiple simulations focused on collisions with Uranus, stating that certain characteristics can be explained by an ancient, calamitous collision that took place roughly 4 billion years ago with an object twice the size of Earth. "We ran more than 50 different impact scenarios using a high-powered supercomputer to see if we could recreate the conditions that shaped the planet's evolution," says Jacob Kegerreis of Durham University's Institute for Computational Cosmology. "Our findings confirm that the most likely outcome was that the young Uranus was involved in a cataclysmic collision with an object twice the mass of Earth, if not larger, knocking it on its side and setting in process the events that helped create the planet we see today." Not only did this collision knock Uranus on its side, but the mystery impactor left a layer of insulating debris that keeps in the internal heat of Uranus. Insulating the ice giant, it would explain why we observe freezing temperatures of -216 degrees Celsius (-357 degrees Fahrenheit) in the planet's outer atmosphere.



© Getty



© NASA/JPL-Caltech

URANUS' UNSETTLED MAGNETOSPHERE

It's been 36 years since Voyager 2's flyby of Uranus, but its data is still fuelling more discoveries. Researchers from the Georgia Institute of Technology used Voyager data to reveal that Uranus' magnetosphere, the region encompassing the planet powered by its magnetic field, turns on and off like a light switch every day as it rotates around the planet. When the magnetosphere is 'open', solar wind is allowed to flow into it; if it's 'closed' it's essentially a shield that guards against the solar wind and deflects it away.

"Uranus is a geometric nightmare," says Carol Paty. "The magnetic field tumbles very fast. When the magnetised solar wind meets this tumbling field in the right way it can reconnect, and Uranus' magnetosphere goes from open to closed to open on a daily basis." The fact that Uranus rotates on its side and its magnetic field is off-centre and tilted by 60 degrees from its axis causes the magnetic field to fall asymmetrically relative to the solar wind direction.

URANUS SMELLS LIKE ROTTEN EGGS

Observations from the Gemini North telescope, located on Hawaii's Mauna Kea summit, revealed that hydrogen sulphide resides in the clouds of Uranus. This gas is what gives rotten eggs their distinctive smell, and it has been found to be one of the key ingredients that make up the clouds. This result came from dissecting the infrared light using Gemini's Near-Infrared Integral Field Spectrometer (NIFS) to reveal the spectral signature of different molecules. "This work is a strikingly innovative use of an instrument originally designed to study the explosive environments around huge black holes at the centres of distant galaxies," says Christopher J. Davis of the United States' National Science Foundation, a leading funder of the Gemini telescope. "To use NIFS to solve a long-standing mystery in our own Solar System is a powerful extension of its use."

By confirming the presence of this smelly gas, it confirms that there are distinct differences between the ice giants, Uranus and Neptune, as well as the other two gas giants, Jupiter and Saturn.

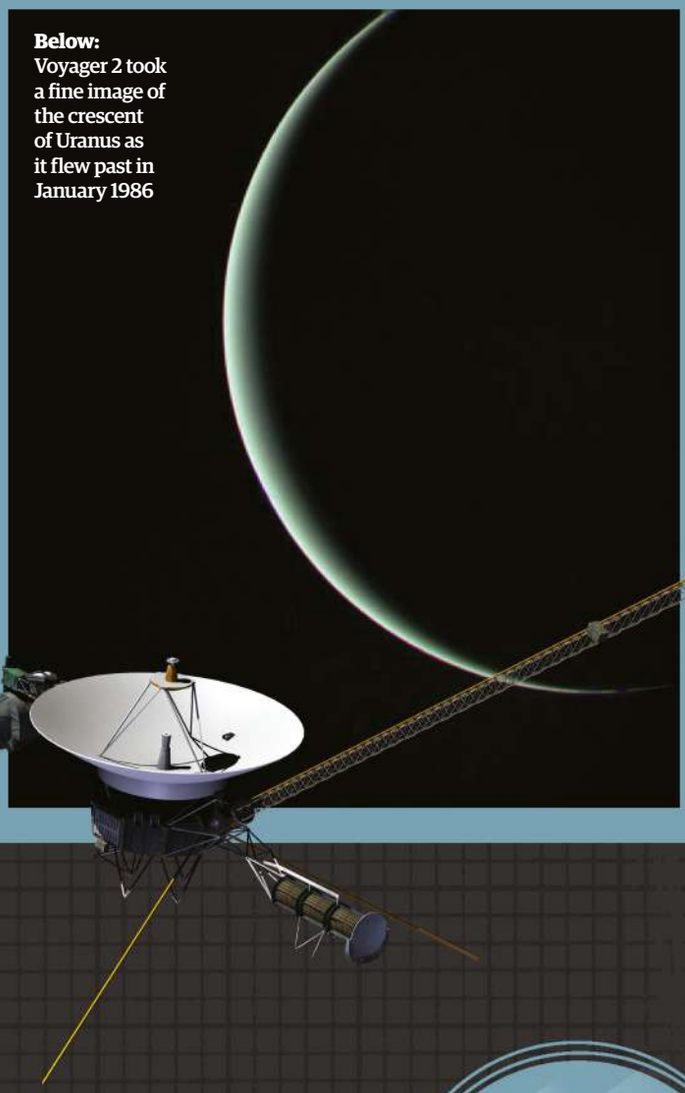
© Gemini

EXPLORATION OF AN ICE GIANT

Uranus is a relatively secluded planet, with a grand total of one spacecraft having visited it in the past. This lone ranger, NASA's Voyager 2 interplanetary probe, flew past the distant ice giant Uranus in 1986 while on its way out of the Solar System. Voyager 2 was able to get within 81,500 kilometres (50,642 miles) of the cloud tops, and its suite of instruments got to work. This flyby provided valuable data of the planet's atmosphere, rings, moons and magnetic field. This included the discovery of 11 new moons, two new rings and revealed that the planet's rotation rate is 17 hours and 14 minutes per rotation.

Although no spacecraft is currently exploring Uranus up close, there are preliminary plans in place to head to both Uranus and Neptune. NASA's Pre-Decadal Survey Mission Study outlines why Uranus and Neptune should be two of the next targets of exploration and contains a variety of potential orbiters, with a probe that could dive into Uranus' atmosphere. There could also be an orbiter carrying a payload between 50 and 150 kilograms for flybys of Uranus' major satellites. There would also be a narrow-angle camera that would be able to image Uranus and its 27 known moons, and possibly discover more.

"We do not know how these planets formed and why they and their moons look the way they do," says Amy Simon of NASA's Goddard Space Flight Center in Greenbelt, Maryland. "There are fundamental clues as to how our Solar System formed and evolved that can only be found by a detailed study of one, or preferably both, of these planets." Not only could these answers help us understand the evolution of our Solar System, but the knowledge could be applied to exoplanets around the galaxy, as ice giants seem to be extremely common within the Milky Way.



Below: Voyager 2 took a fine image of the crescent of Uranus as it flew past in January 1986

© NASA/JPL-Caltech

URANUS FACTS

17

A day on Uranus is 17 hours long, and the planet rotates backwards compared to Earth

Along with Neptune, Uranus is commonly referred to as an 'ice giant', as opposed to a 'gas giant', due to its icy mantle

27

Uranus has 27 known moons, all of which are named after characters from the works of William Shakespeare and Alexander Pope

In Uranus' mantle, the pressure and temperatures are ideal for creating nanosized diamonds, making it theoretically possible for it to 'rain diamonds'

<15x

The winds at Uranus can reach supersonic speeds, creating jet streams which are 10 to 15 times more powerful than anything seen on Earth

90°

Uranus rotates at a nearly 90-degree angle, thought to have been caused by a massive object roughly twice the size of Earth striking it

-218

Uranus is the coldest planet in the Solar System, with a lowest recorded temperature of -218 degrees Celsius (-370 degrees Fahrenheit)

13

Uranus has 13 known rings around it. The inner rings are narrow and dark, while the outer rings are brightly coloured

DID MARS' DEEP INTERIOR CAUSE A LOSS OF ITS ATMOSPHERE?

A new study gives insight into how the Red Planet's magnetic field faded away

Reported by Elizabeth Howell

Key changes deep in the core of Mars might have led to the planet losing its magnetic field early in its history, a new study suggests. Today Mars is a planet with a thin atmosphere that is unable to support substantial running water on the surface, but scientists have found evidence of ancient lakes, streams and perhaps oceans, suggesting that conditions used to be different. Scientists are eager to understand the presence (or absence) of water on Mars in its early history, particularly to inform assessments of the possibility of life on the Red Planet.

In particular, researchers want to understand what might have caused the planet's protective atmosphere to dramatically thin. Now, a new study examines changes in the planet's core that may have led to the magnetic field of Mars weakening over time, leaving the atmosphere vulnerable to erosion. The study team's work suggested that roughly 4 billion years ago within the core, "the behaviour of the molten metal thought to be present likely gave rise to a brief magnetic field that was destined to fade away," representatives of the University of Tokyo, where researchers were based, wrote.

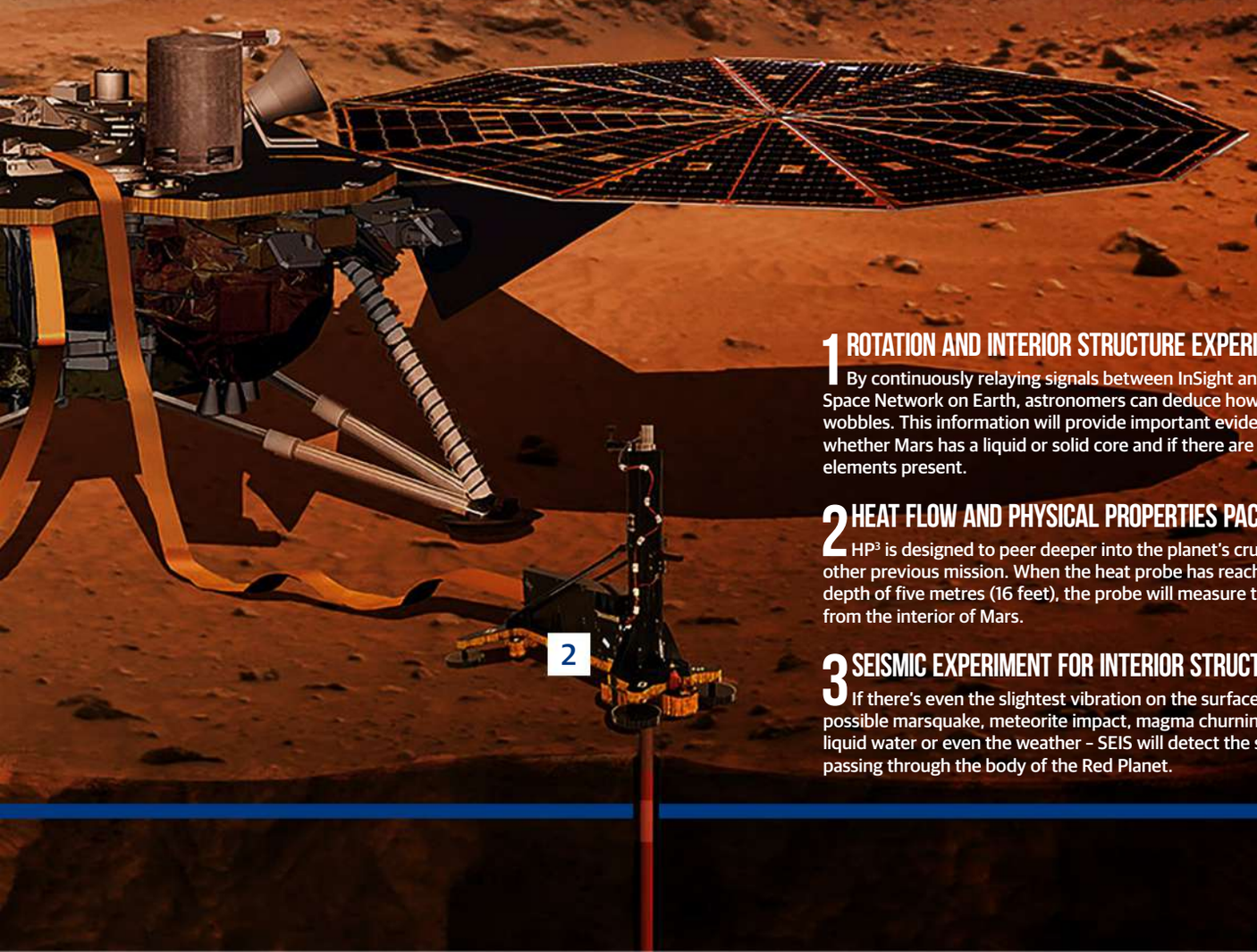
The researchers simulated the conditions of the early Martian core using a sample of material expected to be found there, including iron, sulphur and hydrogen. This sample was placed between two diamonds and compressed, as well as heated, to attempt to replicate the immense pressures and heat found within the core. Using X-ray and electron-beam observations, the team followed the changes in the sample as the material was being pressurised and compressed. The scientists discovered that the initially homogeneous Martian material separated into two liquids.

"One of the iron liquids was rich in sulphur, the other rich in hydrogen, and this is key to explaining the birth, and eventually death, of the magnetic field around Mars," Kei Hirose, a professor at the University of Tokyo's Department of Earth and Planetary Science, said in the same statement. The experiment also showed the less dense hydrogen liquid rose above the much denser sulphur-rich liquid. This liquid movement caused temporary convection currents in Mars, similar to those that are still in place on Earth. Scientists believe these currents generate our magnetic field.

On Mars, however, the magnetic field only lasted temporarily. After the liquids separated, the study suggests, the currents ceased since there was no more activity to drive them.

Around the same time, light hydrogen in the atmosphere blew into space due to erosion from the solar wind, the constant stream of charged particles emanating from our Sun. The lesser atmosphere led to the eventual breakdown of water vapour, as water includes hydrogen. As the atmosphere thinned, liquid water ceased to flow on the surface.

The researchers are hoping that missions such as NASA's InSight lander, which is tracking down seismic activity on the Red Planet, could provide further context concerning core composition. "With our results in mind, further seismic study of Mars will hopefully verify the core is indeed in distinct layers as we predict," Hirose said. "If that is the case, it would help us complete the story of how the rocky planets, including Earth, formed, and explain their composition."



1 ROTATION AND INTERIOR STRUCTURE EXPERIMENT (RISE)
By continuously relaying signals between InSight and the Deep Space Network on Earth, astronomers can deduce how much Mars wobbles. This information will provide important evidence on whether Mars has a liquid or solid core and if there are any other elements present.

2 HEAT FLOW AND PHYSICAL PROPERTIES PACKAGE (HP³)
HP³ is designed to peer deeper into the planet's crust than any other previous mission. When the heat probe has reached its intended depth of five metres (16 feet), the probe will measure the heat coming from the interior of Mars.

3 SEISMIC EXPERIMENT FOR INTERIOR STRUCTURE (SEIS)
If there's even the slightest vibration on the surface of Mars – a possible marsquake, meteorite impact, magma churning underneath, liquid water or even the weather – SEIS will detect the seismic activity passing through the body of the Red Planet.

© NASA/JPL-Caltech

THE MOON-LANDING HOAX

WHY DOES THE THEORY STILL LIVE ON? [redacted] ALL ABOUT SPACE DEBUNKS A HOAX THAT RAGES AMONG [redacted] CONSPIRACY THEORISTS EVER SINCE [redacted] NEIL ARMSTRONG AND BUZZ ALDRIN LANDED ON THE LUNAR SURFACE

Reported by Elizabeth Howell, Robert Myers and Robert Z. Pearlman

The Moon-landing hoax still lives on more than 50 years after Apollo 11 – the first crewed mission to land on the Moon. Phil Plait has mixed feelings about the Moon-landing hoax. Plait – known as 'the Bad Astronomer' to his many thousands of readers on Syfy – reveals he is frustrated that he and others like him still have to debunk the hoax theory from time to time, over 50 years after the first Moon landing. Then again, Plait became famous because he's so good at debunking in the first place.

Back in February 2001, Fox Broadcasting ran a documentary titled *Conspiracy Theory: Did We Land on the Moon?* Plait coincidentally had a pile of research ready from a book he was working on, and a friend sent him an advance copy of the show so that he had time to write up a response. Plait's essay on his personal blog, which he published shortly after the show aired, quickly generated thousands of views years before Facebook, Twitter and today's social media even existed.

Fox's TV show propelled Plait's writing to a large audience, and his 2002 book *Bad Astronomy: Misconceptions and Misuses Revealed, from Astrology to the Moon Landing 'Hoax'* helped as well. Plait remains a popular science commentator nearly two decades later. "I kind of wish it had never aired," Plait says about the Fox documentary, "because it opened a huge Pandora's box. On the other hand, it's exposing a wound to sunlight. That thing was there anyway, festering. Let it get out to the public, and let it heal, and let it kill the infection. But yeah, it's troubling just to know that if Fox hadn't aired that, who knows what my career path would have been."

Apollo 11 astronauts Neil Armstrong and Buzz Aldrin stepped onto the lunar surface on 20 July 1969. Even back then, some people were sceptical that the feat was technologically possible. The James Bond movie *Diamonds Are Forever*, for example, had a joke about faked Moon landings just two years later, in 1971. But what really propelled the conspiracy theory into popular culture, Plait says, was the 1978 Peter Hyams film *Capricorn One*, which portrays a faked human landing on Mars. Also, a 1976 self-published pamphlet by Bill Kaysing, *We Never Went to the Moon*, was popular among conspiracy-minded people of the day. That was over 40 years ago, but Moon-hoax enthusiasts are still with us today.

[redacted]

HOAX THEORY #1

FLUTTERING FLAG

THE CLAIM: THE AMERICAN FLAG APPEARS TO WAVE IN THE LUNAR 'WIND'

The science: If you look closely, you'll notice that the flag's edges are pulled taut. This effect, which was done purposely so as to not allow the flag to just hang flat, was created by inserting a stiff wire into the fabric. The 'flutter' was created as the astronauts worked to erect the flag. As the wire was adjusted, 'Old Glory' appeared to wave.

GLOW-IN-THE-DARK ASTRONAUTS

THE CLAIM: IF THE ASTRONAUTS HAD ACTUALLY CROSSED THE VAN ALLEN BELT, THE RADIATION WOULD HAVE KILLED THEM

The science: The Van Allen belts are created by Earth's magnetic field, and protect the planet from dangerous solar radiation. The belts collect this radiation and trap it in a layer surrounding Earth. But unless you deliberately caused your spaceship to hover within this layer for many hours or days, the radiation exposure is well below dangerous levels, like getting an X-ray.

HOAX THEORY #2

All images © NASA (unless stated otherwise)

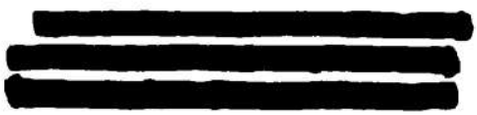
HOAX THEORY #3

THE SHADOW KNOWS

THE CLAIM: MULTIPLE-ANGLE SHADOWS IN THE MOON PHOTOS PROVE THERE WAS MORE THAN ONE SOURCE OF LIGHT, LIKE A LARGE STUDIO LAMP

The science: The astronauts were taking their photos on a hilly, brightly lit landscape while the Sun was close to the horizon. Imagine taking a photograph of someone on a rolling, uneven field of snow during a full, low-hanging Moon. The contours of the ground would produce shadows of many different lengths.

The X-Files brought all sorts of space conspiracies into the public consciousness in the 1990s and 2000s, and the rebooted version of the show addressed the Moon landing in a 2018 episode. The conspiracy was also addressed in many other fictional TV shows, from *Futurama* to *Friends*. Meanwhile, some documentary films and reality TV efforts – a 2008 episode of *MythBusters*, for example – tried to chase away



the conspiracy theory by educating people. Other filmmakers, such as the folks behind the 2002 mockumentary *Dark Side of the Moon*, spoofed Moon hoaxers.

Opinion polls over the years regularly show that around five per cent of Americans believe the Apollo Moon landings were faked, former NASA chief historian Roger Launius confirmed. That's more than 16 million people, assuming a US population of 327 million.

NASA has done a lot of debunking work over the decades, including a 2018 offer to NBA superstar Stephen Curry to view Moon rocks at the NASA Johnson Space Center in Houston after Curry said he didn't believe in the Moon landings. A few days later, Curry said he made the comments in jest.

AMAZING FACTS ABOUT THE APOLLO PROGRAM

THE APOLLO PROGRAM COST $200 BILLION

In the early 1960s, the initial estimated cost of the Apollo program was around £5.3 billion ($7 billion), revised to £15.9 billion ($20 billion) by NASA administrator James E. Webb. By the end of the program in 1973, total research and development costs of the 17 missions had cost the US government £18 billion ($23.9 billion), equivalent to around £151 billion ($200 billion) in today's money.

APOLLO 1 MET A TRAGIC END

Designated Apollo Saturn-204 or AS-204, the first manned Apollo mission was scheduled to launch on 21 February 1967, but never made it. During a launchpad test on 27 January, a cabin fire broke out, destroying the Command Module and killing all three of its crew: commander Gus Grissom, senior pilot Edward White and pilot Roger Chaffee. The widows requested that the test flight be renamed as the first Apollo mission, and NASA formally retired the Apollo 1 name.

NASA ERASED THE APOLLO 11 FOOTAGE

Unbelievably, the video recording of the original Apollo 11 Moon landing was erased in subsequent years. NASA had a shortage of magnetic tape in the years following the famous 1969 mission and simply recorded over it, kicking themselves 40 years later on the anniversary when the agency wanted to digitally restore the original analogue recording.

APOLLO USED 3 MILLION LITRES OF FUEL

The Apollo program's Saturn V launch vehicle used a total of around 3.6 million litres of fuel to land humans on the Moon. With a fuel efficiency of 12 kilometres (7.4 miles) per litre, you could drive for nearly 30 million kilometres (18.6 million miles) on a tank that size, or 400 times around Earth. That much fuel aboard the Saturn V increased its weight by 2.55 million kilograms.

APOLLO'S POWER COULD LIGHT A CITY

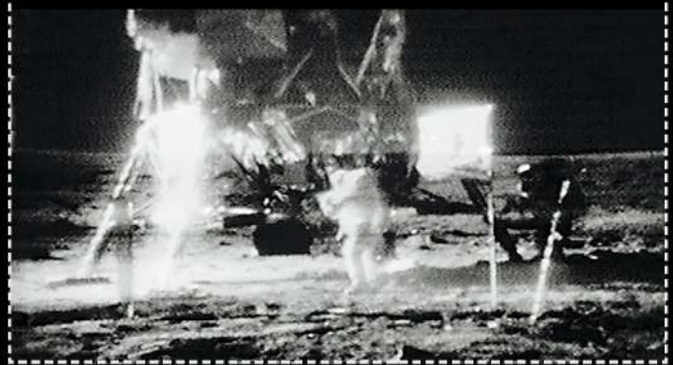
The energy generated by the Apollo spacecraft's reentry into the atmosphere was incredible. It was the equivalent of 86,000 kilowatt-hours of electricity, which is enough to illuminate all of Los Angeles' street lights for 104 seconds.

HOAX THEORY #4

FRIED FILM

THE CLAIM: IN THE SUN'S RAYS, THE MOON'S TEMPERATURE IS TOASTY 137 DEGREES CELSIUS (280 DEGREES FAHRENHEIT). THE FILM WOULD HAVE MELTED

The science: No one was leaving bare film out on the hot lunar surface. All material was contained in protective canisters. In addition, at the time the Apollo missions landed, they were either at lunar dawn or dusk, so the temperature was more manageable.

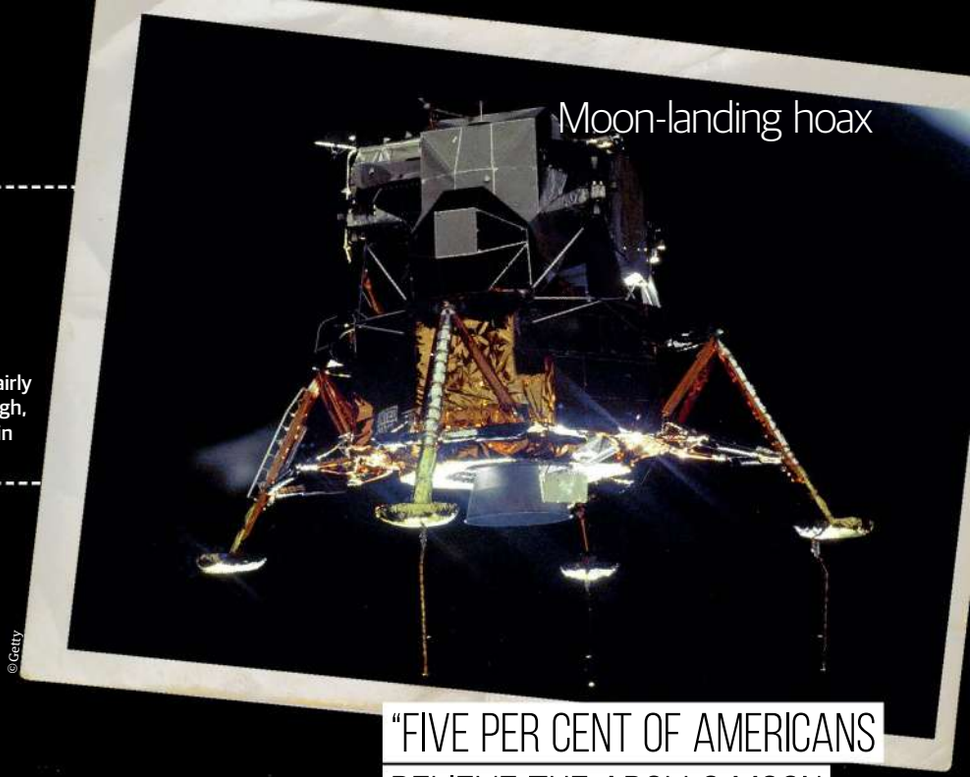


HOAX THEORY #5

NO CRATER AT THE LANDING SITE

WHEN THE LUNAR MODULE LANDED, ITS POWERFUL ENGINE DIDN'T BURROW A DEEP CRATER IN THE DUSTY SURFACE

The science: Beneath the layer of dust, the Moon is made of fairly densely packed rock. What dust and loose dirt there was, though, was 'kicked up', as referenced by the astronauts and captured in their landing films.

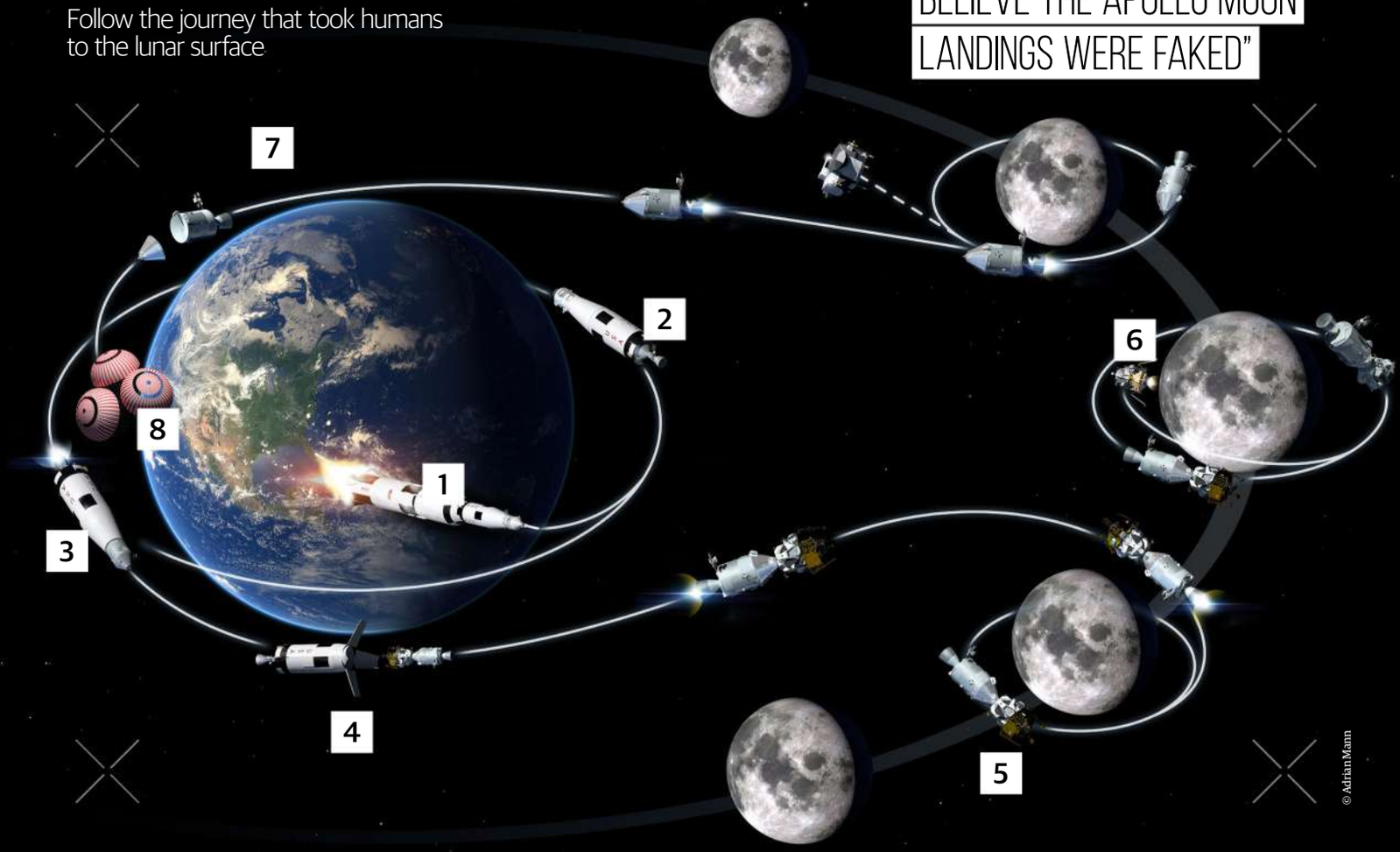


© Getty

"FIVE PER CENT OF AMERICANS BELIEVE THE APOLLO MOON LANDINGS WERE FAKED"

APOLLO 11'S FLIGHT PATH

Follow the journey that took humans to the lunar surface



© Adrian Mann

LIFTOFF

Date: 16 July 1969
Time: 13:32:00 (UTC)

1 The three-stage Saturn V rocket launched Apollo 11 from the Kennedy Space Center in Florida.

INITIAL PARKING ORBIT

Date: 16 July 1969
Time: 13:43:49

2 The craft, still attached to the Saturn V's third stage, orbited Earth while final checks were done.

TRANSLUNAR INJECTION

Date: 16 July 1969
Time: 16:22:13

3 The third stage fired up again, putting Apollo 11 on a trajectory that would take it to the Moon.

LINKUP WITH LUNAR MODULE

Date: 16 July 1969
Time: 16:56:03

4 The Command Module docked with the Lunar Module as the empty third stage was jettisoned.

ENTERING LUNAR ORBIT

Date: 19 July 1969
Time: 17:21:50

5 On arrival at the Moon, the Service Module engine fired up to put the spacecraft into orbit.

THE LANDING

Date: 20 July 1969
Time: 20:17:40

6 Armstrong and Aldrin descended to the surface in the Lunar Module before ascending to rejoin Collins.

LEAVING LUNAR ORBIT

Date: 21 July 1969
Time: 23:41:31

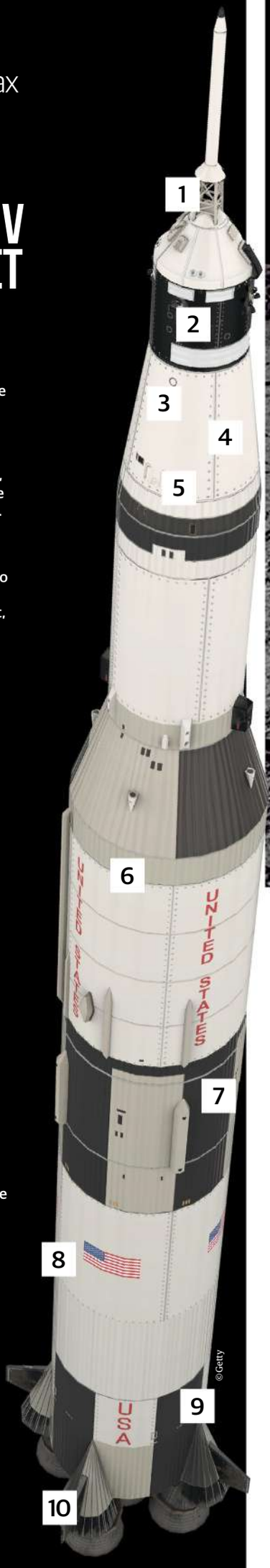
7 After the Lunar Module was jettisoned, the Service Module put Apollo on a trajectory home.

SPLASHDOWN

Date: 24 July 1969
Time: 16:50:35

8 Finally the Service Module was discarded, leaving just the Command Module to splash down in the Pacific Ocean.

ANATOMY OF THE SATURN V MOON ROCKET



1 LAUNCH ESCAPE SYSTEM
Thankfully it wasn't needed, but this was there to whisk the Command Module to safety if the rocket failed on launch.

2 COMMAND MODULE
The main crew compartment, where Collins remained while the others descended to the surface.

3 SERVICE MODULE
An essential part of the Apollo spacecraft, it provided power, communications and life support, as well as propulsion.

4 APOLLO SPACECRAFT
The Saturn V's all-important payload, this was the part that actually travelled to the Moon.

5 LUNAR MODULE
This consisted of the crew-carrying ascent stage on top of the four-legged descent stage, which remained on the Moon.

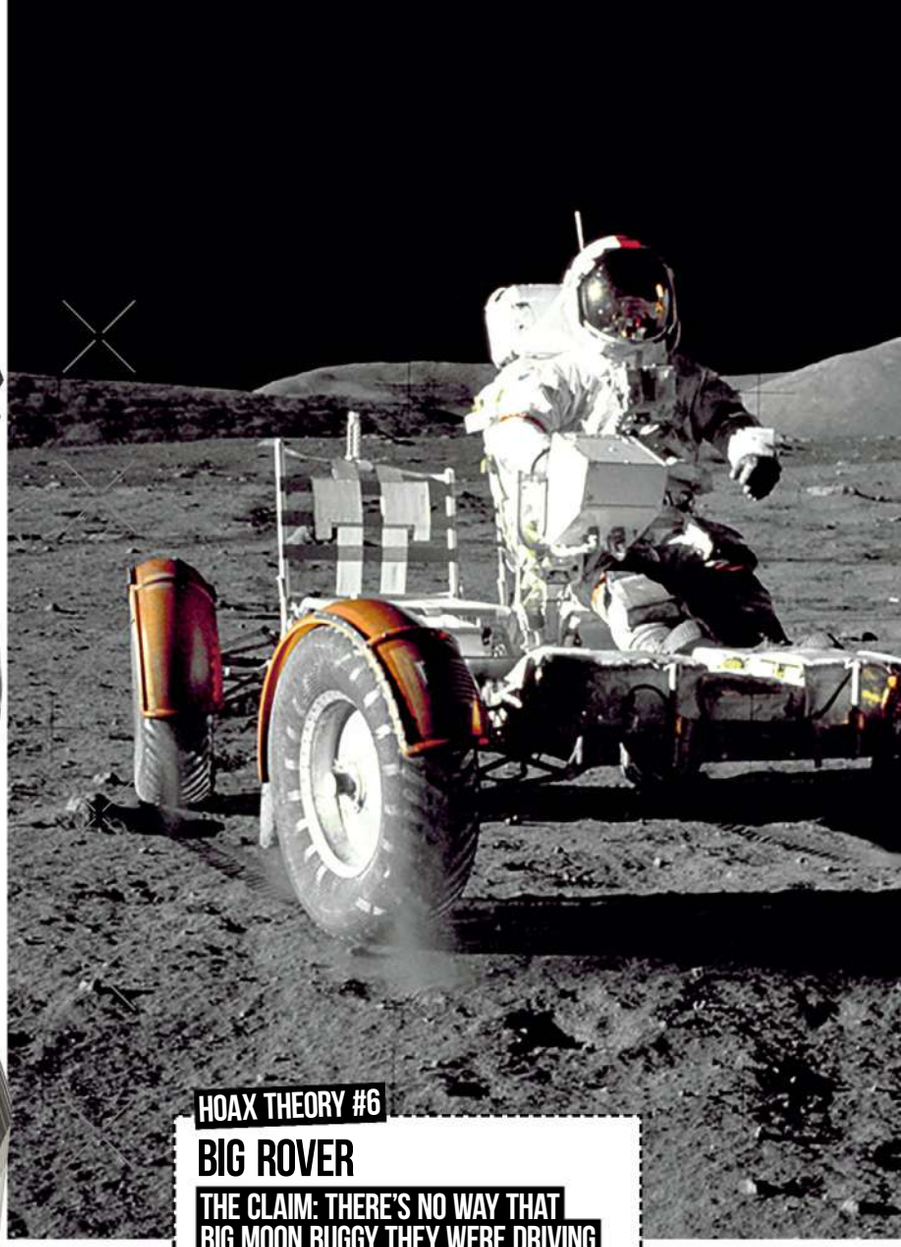
6 INSTRUMENT UNIT
It may look small and insignificant, but this was the brain of the Saturn V – its guidance computer.

7 THIRD STAGE
The third stage was fired twice: once to enter Earth orbit and then again to push onwards to the Moon.

8 SECOND STAGE
Using liquid-hydrogen fuel, the second stage took over for another six minutes, getting close to orbital velocity.

9 FIRST STAGE
The Saturn V's kerosene-fuelled first stage lifted it to an altitude of 68 kilometres (42 miles) in 165 seconds before falling away.

10 MAIN ENGINES
A cluster of five rocket engines, each over five metres (16.4 feet) tall, was needed to lift the near-3,000-tonne giant rocket off the ground.



HOAX THEORY #6

BIG ROVER

THE CLAIM: THERE'S NO WAY THAT BIG MOON BUGGY THEY WERE DRIVING COULD HAVE FIT INTO THAT LITTLE LANDING MODULE

The science: The rover was very cleverly constructed to be made out of very light materials and was designed to fold up compactly – a real-life Transformer.

In early 2019, NASA spokesperson Allard Beutel recited a pile of evidence supporting the Moon landings to *the Washington Post*. He mentioned the returned Moon rocks, the ability to bounce laser beams off gear the astronauts left behind and images NASA's Lunar Reconnaissance Orbiter took of the Apollo landing sites in 2011. Nevertheless, even former astronauts have found themselves in the fray. Space Shuttle astronaut Leland D. Melvin tackled the topic in the 2019 Science Channel series *Truth Behind the Moon Landing*. And in 2002 Apollo 11 astronaut Buzz Aldrin punched Moon-landing denier Bart Sibrel in the jaw during a taped confrontation. Police later said Aldrin was provoked, and no charges were filed.

Plait says there is a danger in talking about the Moon-landing conspiracy and other clearly debunked conspiracies like it, such as vaccines causing autism or humans not being responsible

HOAX THEORY #7

LIQUID WATER ON THE MOON

THE CLAIM: TO LEAVE A FOOTPRINT REQUIRES MOISTURE IN THE SOIL

The science: Not always. If you take some dry, fine-grained dust such as talcum powder and dump it out, it's easy to make tracks in it that hold their shape. The particles hold their positions due to the friction between them.

for climate change. It's possible, he states, that by airing any of these debates, the media gives legitimacy to the conspiracy. Plait admits he sometimes struggles about whether to address a conspiracy in his blog; he tries to discuss ones that are widely talked about already, but it's a tough job in fast-moving social media. Plait says he recently commented on what appeared to be widespread Twitter backlash about the new version of *The Little Mermaid* starring black actress Halle Bailey, only to discover the backlash was itself likely faked. Plait took down his original tweet and wrote a correction. The genesis of the viral tweet was from a troll account, according to a tweet by Buzzfeed's Brandon Wall.

[redacted]

Plait says we should remember that conspiracy beliefs often have real-life effects: "Because of the anti-vax movement, babies are dying, kids are dying, older people are dying, people with compromised immune systems are dying." Extreme weather events driven in part by climate change are killing people as well, he says.

Plait clarifies that he doesn't blame any particular political position for this strife – not even the alt-right, as it doesn't "play into their ideology," which he says targets people of certain religious groups. But nevertheless, he adds, "all of this stuff has been corralling the imagination of the American public and forcing it in a direction to not think critically, and to react instead of sitting and thinking a moment about things, and to doubt – even when you can lay a paper trail from point A to point B right in front of someone, they won't believe it."

But Plait still tries. He remembers being on a radio show not too long ago, going over the usual arguments conspiracy theorists use. For example, why are there no stars in the sky in Apollo pictures of the lunar surface? The reason is that the cameras had fast exposure times and the stars were too faint to show. "Then somebody called in with some bizarre, trivial thing that made no sense at all," Plait recalls. "And bless him, the radio host jumped in and said, 'Listen. This guy said your ten biggest claims are wrong. At what point do you back down?'"

"PLAIT SAYS THERE IS A DANGER IN TALKING ABOUT THE MOON-LANDING CONSPIRACY AND OTHER CLEARLY DEBUNKED SPACE CONSPIRACIES LIKE IT"

Elizabeth Howell
Space.com contributor
Elizabeth is a contributing writer for **space.com** since 2012. She tackles topics like spaceflight, diversity, science fiction and astronomy.

Robert Z. Pearlman
Science journalist and editor
Robert is a space historian, journalist and founder and editor of **collectspace.com**, an online community devoted to space history.

All About Space | Subscription offer

SUBSCRIBE TODAY AND SAVE 50%

WHY DOES THE MOON-LANDING HOAX STILL EXIST?
All About Space
FUTURE TECH
HOW TO AVOID AN ASTEROID IMPACT
SECRETS OF BLACK HOLES
THE TRUTH ABOUT THE COSMOS' MOST MIND-BENDING PHENOMENA
HOW DID EARTH GET ITS WATER?
BUZZ ALDRIN
MOON & NIGHT SKY TOUR
SPECIAL FEATURE
HOW MANY STARS ARE IN THE UNIVERSE?
Q&A WITH NASA & MORE
EXPERTS SOLVE SPACE'S GREATEST MYSTERIES
REVIEWED
CANON 10X42L IS WP BINOCULAR
EVERYTHING YOU NEED TO KNOW ABOUT URANUS
All About Space
SUBSCRIBER EDITION
SECRETS OF BLACK HOLES
TIME-LIMITED OFFER!

SAVE 34%

£11.75
THREE-MONTH PRINT

SAVE 50%

£61.50
ANNUAL BUNDLE

SAVE 34%

£8.50
THREE-MONTH DIGITAL

All About Space | Subscription offer

All About Space **EXCLUSIVE** SUBSCRIBER-ONLY COVER!

Reasons to subscribe…

- **You'll never miss an issue!**
- **It's delivered direct to your door**
- **Brilliant value – great savings on the cover price**
- **Special subscriber covers**

Subscribe now

www.magazinesdirect.com/aas/A15X
or call 0330 333 1113 and quote A15X

£11.75 every three months

13 issues of **All About Space** in print over 12 months

SAVE 34%

£61.50 every 12 months

13 issues of **All About Space** in print and digital over 12 months

SAVE 50%

£8.50 every three months

13 issues of **All About Space** in digital

SAVE 34%

*Terms and conditions: Offer closes 30 April 2022. Offer open to new UK subscribers only. Pricing is guaranteed for the first 12 months and we will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. The full subscription rate is for 12 months (13 issues) and includes postage and packaging. If the magazine ordered changes frequency per annum, we will honour the number of issues paid for, not the term of the subscription. For full terms and conditions, visit **www.magazinesdirect.com/terms.** For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday to Friday 9am to 5pm UK time or e-mail: **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

Focus on

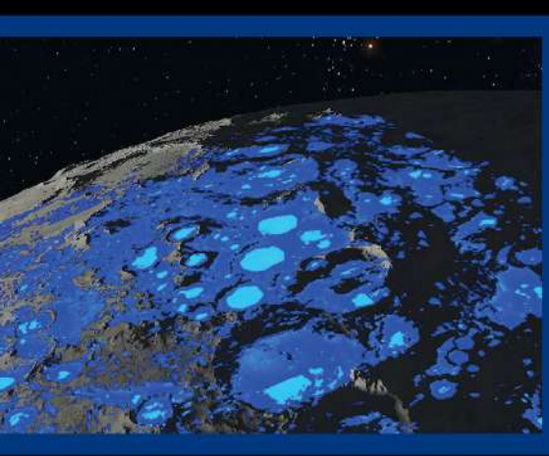
HOW DID EARTH GET ITS WATER?

Moon rocks suggest that the water might have been here all along

Reported by Charles Q. Choi

Earth's water may have been here since the planet formed, and not delivered later by collisions with icy comets. New research analysed Moon rocks brought to Earth by the Apollo program and sheds light on our planet's earliest days. Although more than 70 per cent of Earth's surface is covered in water, overall our planet is relatively poor in water and other volatile molecules compared with most other bodies in the Solar System, said Lars Borg, a planetary scientist at Lawrence Livermore National Laboratory in California.

Scientists have long debated how Earth came to possess water. Two major scenarios prevail, and both involve ancient cosmic impacts, the most notorious of which saw the proto-Earth collide with a Mars-size rock dubbed Theia that helped give birth to the Moon. In the first scenario, "Earth is born dry and inherits its water through the addition of material from water-rich bodies such as comets and primitive meteorites," Borg said. "In the second, Earth forms with volatile element abundances that are similar to the Solar System average, but loses most of them during the giant impact that formed the Moon."

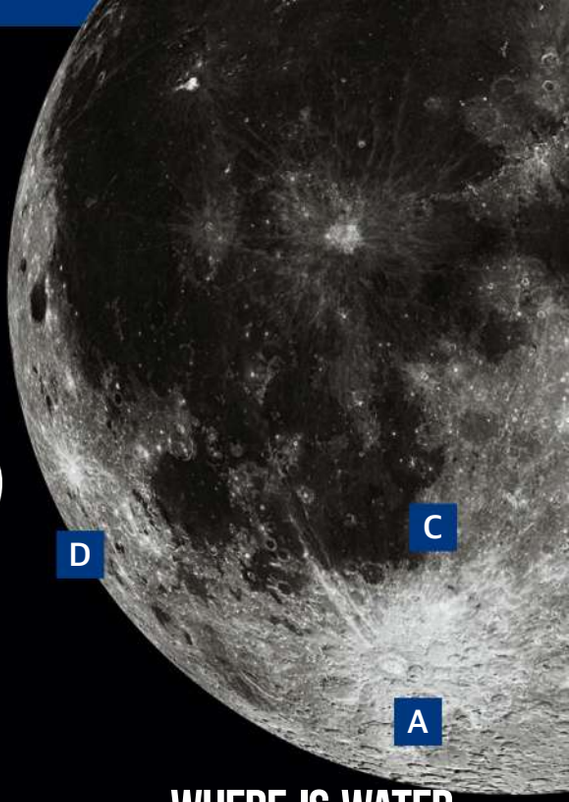


© ESA

To help solve this mystery, scientists analysed rocks from the Moon collected during the Apollo missions. The researchers focused on levels of rubidium-87, which is volatile and radioactive, and strontium-87, the stable product of its radioactive decay. They found that levels of strontium-87 were relatively low in lunar highland rocks that crystallised around 4.35 billion years ago, suggesting that levels of rubidium-87 and other volatiles were similarly low in Earth and the Moon when they formed. But that conclusion contradicts both of the major theories for how Earth got its water.

"Our work suggests that Earth and the Moon formed with about the same amounts of volatile elements as they have today," Borg said. "This doesn't mean that no water was added to Earth by comets and meteorites, but simply that the majority of water was inherited from the materials that Earth and the Moon formed from." These findings suggest that both Theia and the proto-Earth were strongly depleted in volatile compounds before the massive collision. This hints that both bodies formed in the inner Solar System relatively late in the Solar System's history, after 4.45 billion years ago, when the young Sun's heat would have baked many of the volatiles out of these bodies.

These findings may also help explain other mysteries regarding the origin of Earth and the Moon. "These include explaining the baffling observation that Earth and the Moon have similar oxygen, chromium and titanium isotopic compositions when most formation models predict they should be different," Borg said.



Left: A map of possible water at the lunar south pole based on data from a NASA lunar orbiter

WHERE IS WATER ON THE MOON?

A WATERY CHEMISTRY IN CLAVIUS CRATER

The detection of water molecules in Clavius, one of the largest craters visible from Earth, hinted at some degree of surface-wide hydration of the lunar regolith.

B DIRTY POLAR ICE

The Lunar and Planetary Institute's Paul Spudis used Chandrayaan-1's radar data to estimate that 600 million tonnes of water ice could be locked up in just 40 polar locales.

C MAPPING THE POLES

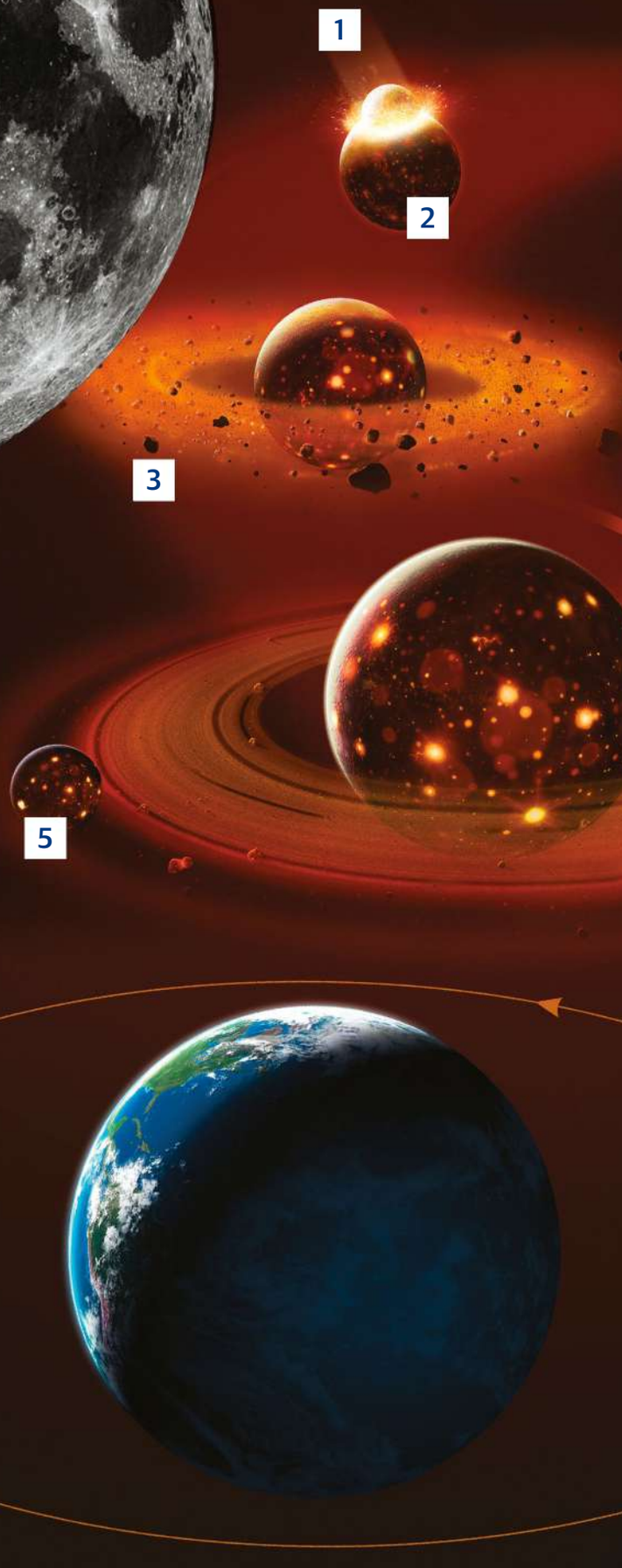
The pole-to-pole orbit of Chandrayaan-1 allowed NASA's onboard Moon Mineralogy Mapper instrument to map the surface ice across the Moon's southern pole.

D A WISPY, WATERY ATMOSPHERE

It's believed that water molecules freed from lunar regolith grains by the warming Sun might bounce across the surface, travelling through the Moon's thin exosphere.

E VOLCANIC WATER

In 2017, Hawaii University's Shuai Li found evidence of water in large pyroclastic deposits, including those found near the Apollo 15 and 17 landing sites.



HOW THE MOON WAS MADE

1 THEIA APPROACHES THE PROTO-EARTH

A Mars-sized object entered an unalterable collision course with the early Earth, forming the Moon that we see today.

2 EARTH TAKES A BIG HIT

The impactor hit Earth in a head-on collision, vaporising both Theia and Earth's mantle as it struck.

3 MATERIAL GETS THROWN OUT

The vaporised material from both bodies mixed and was thrown outwards by the huge impact.

4 DEBRIS BEGINS TO GATHER

Smaller objects began to condense out of the vapour while continuing to orbit around Earth.

5 THE MOON TAKES SHAPE

Many of the smaller objects stuck together to form a proto-Moon in orbit around Earth.

6 OUR COMPANION IS FORMED

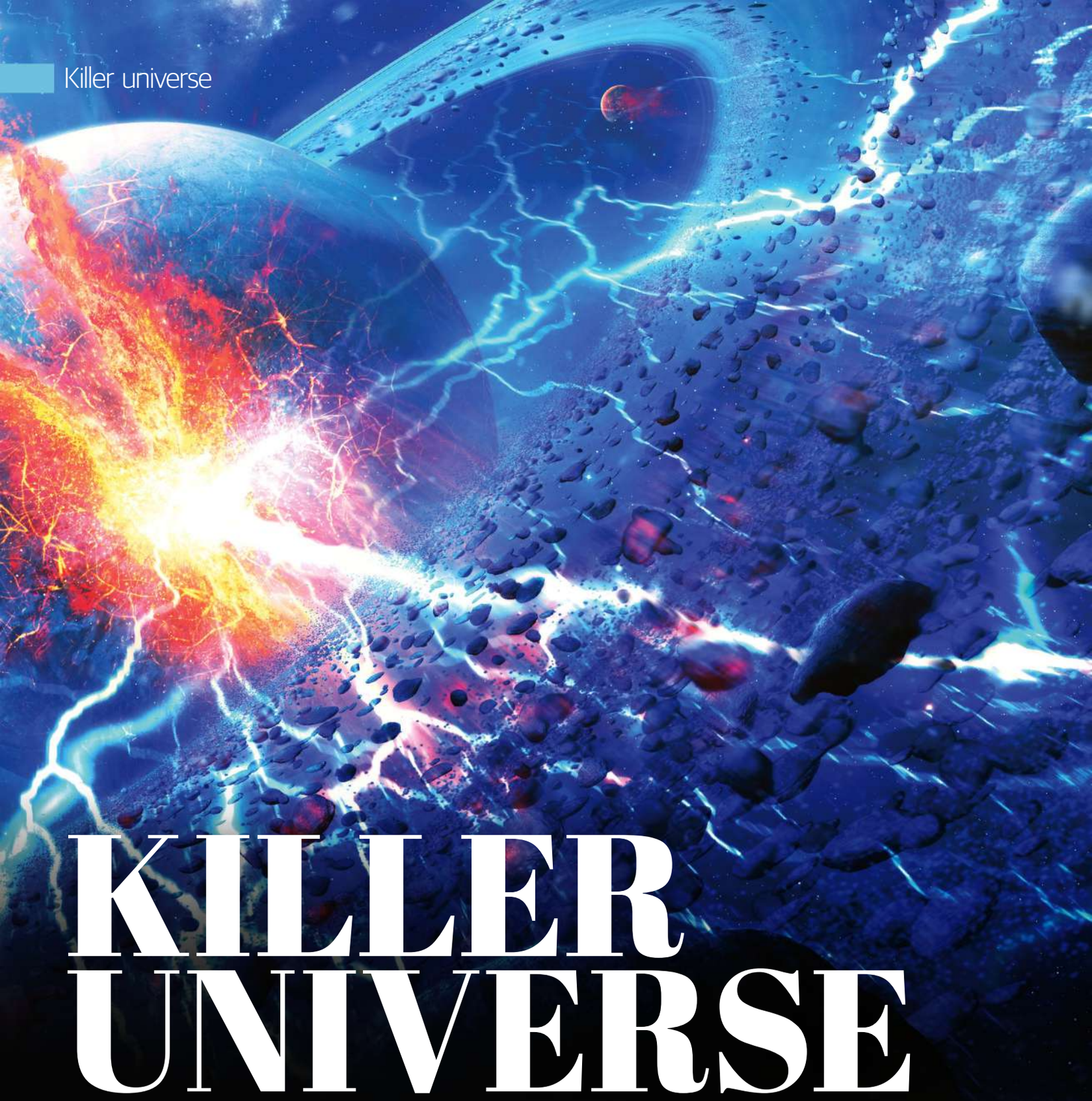
Eventually all the pieces came together to form the basis of the Moon we see today.

© Getty

Above: The proto-Earth had many calamitous encounters with other bodies

"EARTH AND THE MOON FORMED WITH ABOUT THE SAME AMOUNTS OF VOLATILE ELEMENTS AS THEY HAVE TODAY" LARS BORG

© Science Photo Library



KILLER UNIVERSE

RELATIVELY SAFE IN OUR PROTECTIVE BUBBLE, SOME FORCES COULD END LIFE ON EARTH FOREVER. IS THE COSMOS OUT TO GET US?

Written by Nikole Robinson

While Earth isn't free of destructive impulses – natural disasters, climate change, radioactive rocks and deadly viruses, to name but a few – it's a relatively safe haven for humans among the stars, hence why humans have managed to evolve to live here so successfully. But leaving the confines of our planet's protective atmosphere, the universe gets a lot deadlier. As it turns out, space isn't the most welcoming place for us Earth dwellers, with many ways the universe could wipe us all out in just the blink of an eye.

© NASA/ESA

1 A GAMMA-RAY BURST MELTS THE ATMOSPHERE

Gamma-ray bursts (GRBs) are the most intense, high-energy radiation events in the universe, thought to be produced from explosive cosmic events like hypernovae, black hole formation and colliding neutron stars. Though these beams typically last just a few seconds, they release 10 billion years of solar energy in this tiny timeframe.

We've only observed GRBs in distant galaxies so far, but there's no reason the same physics couldn't apply in our Milky Way. If a nearby event triggered such a burst, and the electromagnetic beam was directed straight at our planet, we wouldn't feel any immediate effect. However, the intensity of the radiation would strip away the ozone layer of our atmosphere in mere seconds, leaving us vulnerable to cosmic rays and the full ultraviolet radiation that the Sun sends our way. And because of the split-second nature of GRBs, it would be nigh impossible to predict when one could strike us. It also might not be the first time: a local GRB is one theory put forward to explain the Late Ordovician mass extinction – one of Earth's five major extinction events – which took place around 450 million years ago, wiping out 85 per cent of species in our primitive oceans.

"IF ANYTHING WERE TO UPSET THIS BALANCE, OUR STAR COULD START TO DIE, WITH EARTH FOLLOWING SUIT"

Source: Wikipedia Commons © Fsgregs

Above: Artist's impression of a beam of gamma radiation firing into the cosmos

Left: A Sun-scorched Earth would be left uninhabitable

Right: Magnetars are extremely powerful neutron stars

2 MURDEROUS MAGNETARS

When a star dies, if it falls in a certain mass range it can collapse into a neutron star, a super-dense, city-sized stellar corpse. These cosmic cadavers can have extreme magnetic fields – up to 1,000 trillion times that of Earth – and these are dubbed magnetars. Out of about 3,000 known neutron stars in our galaxy, 31 are confirmed to be magnetars, making them quite the rarity. However, if Earth were somehow to come within 1,000 kilometres (621 miles) of one of these magnetic monstrosities, we would all be doomed. The fatal attraction of its magnetic field would start to destabilise our atoms, ripping the electrons from everything on Earth and reducing all life to ion clouds. As well as having the most intense magnetic fields in the universe, these stellar remnants also produce a great deal of radiation across the electromagnetic spectrum, and may even be a source of potentially deadly GRBs.

© Getty

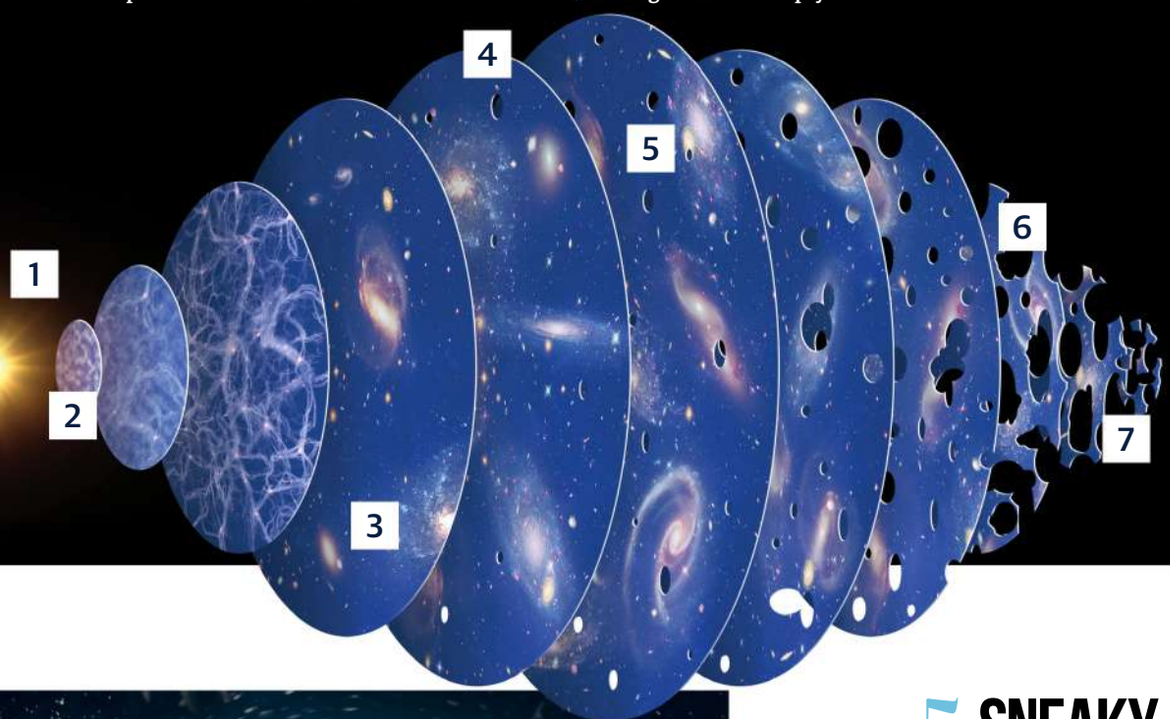
3 PREMATURE DEATH OF THE SUN

The Sun is a ticking nuclear bomb, and it will take Earth and the other inner planets with it when it dies. As it runs out of hydrogen to fuse, it will cool and swell into a red giant, sending out waves of intense radiation as it fuses heavier elements within before shrinking into a white dwarf after these alternative fuel sources also run dry. Approximately halfway through its stellar life cycle and not predicted to run out of fuel for another 5 billion years – at which point we will either already be extinct or have become an interplanetary species – unknown processes or interference could shorten the life of our star and cause it to swell sooner or more rapidly than predicted. Our host is currently in equilibrium, with the inward force of gravity balanced by the outward force of thermal pressure from the nuclear fusion that powers it. But if anything were to upset this balance, our star could start to die, with Earth following suit.

4 THE BIG RIP TEARS EVERYTHING APART

When astronomers first tried to measure the expansion of the universe using the Hubble Space Telescope in 1998, they expected it to have slowed down since the Big Bang blasted everything into existence 13.8 billion years ago. But they were surprised to find out expansion is actually accelerating, with galaxies moving away from each other at an ever-quicker pace. Though we still don't know for sure what's causing the increase in speed, the blame has been put on dark energy, a mysterious and invisible repellant force which makes up around 68 per cent of the entire universe.

Some scientists think that dark energy's influence is increasing, and that at some point in the future the expansion-accelerating force could completely overpower the forces that hold everything together, from your atoms to the biggest galaxies. First it will overpower gravity – the weakest of the four fundamental forces – tearing apart galaxies, then the stellar systems within them. Eventually it will affect the strong nuclear force which holds together the protons and neutrons that make up our very atoms, tearing up the building blocks of everything and leaving behind an empty universe.



1 BIG BANG
The universe began from an infinitesimally small point 13.8 billion years ago: a singularity.

2 INFLATION
Our universe expanded rapidly, increasing in size by up to 100 times or more.

3 FIRST STARS
The first stars formed 300 million years after the Big Bang, with gravity pulling them together to form galaxies on a local scale.

4 ACCELERATING
Space-time is being pulled apart at a faster and faster rate.

5 GRAVITY
Once the expansion of the universe reaches a certain speed, gravity will no longer be able to hold objects together, and the universe will head to its doom.

6 TORN APART
Eventually space-time will be expanding so fast that galaxies will be pulled apart, followed by stars and planets.

8 THE BIG RIP
Everything will move away from everything else so quickly that none of the forces will be able to keep atoms together, tearing everything apart.

© Tobias Roetsch

© Getty

Above: Concept of the expansion of the universe and the Big Rip

Left: Small black holes would be extremely hard to identify

5 SNEAKY STELLAR-MASS BLACK HOLE

While we can be safe in the knowledge that the supermassive black hole at the centre of the Milky Way is unable to gobble up our whole galaxy – and we're safely sitting 26,000 light years from the galactic centre where it dwells – smaller, sneakier black holes could come close enough to start pulling in the Solar System if one headed our way. Stellar-mass black holes are super-dense singularities with masses less than 100 times that of the Sun. There are thought to be around 100 million of these dinky devourers in the Milky Way, though most discovered so far have been found in binary pairs. When they have a partner feeding them material, they are much easier to detect, since we can see their interactions. But a hungry lone roamer with the right mass would be practically undetectable until it started turning our Sun into spaghetti. As this would be our first hint at its approach, we'd just have to watch the Sun be slowly swallowed and accept our fate.

© Tobias Roetsch

Left: The force of a supernova could shatter nearby planets

6 LOCAL SUPERNOVA

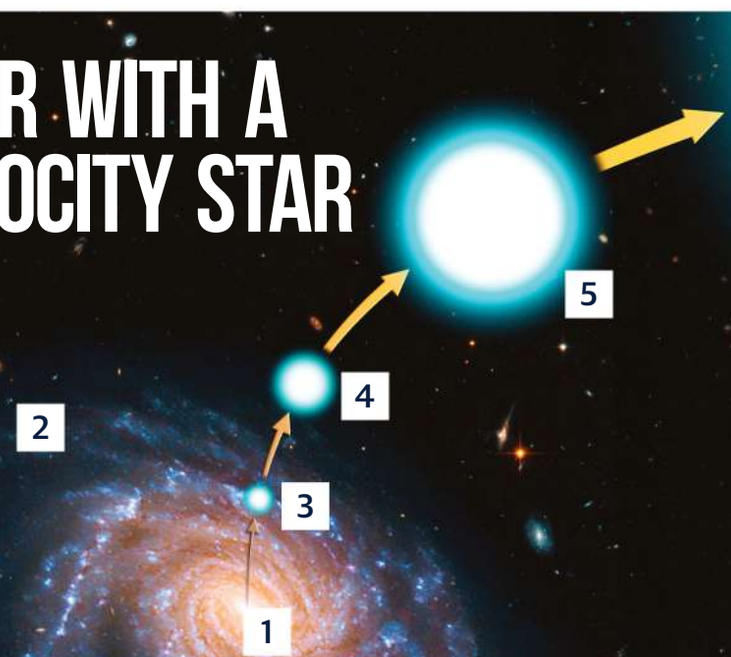
When a large enough star dies, it goes out with a bang, spreading material and radiation into the cosmos. Though astronomers have calculated that Milky Way supernovae should occur every 50 to 100 years on average, we seem to have waited a while, and only five naked-eye supernovae exist in historical records. But how close would one have to be to affect Earth? According to NASA, within about 50 light years. We're safe from this threat for now, as the nearest supernova candidate to us, IK Pegasi B, is 150 light years away. Betelgeuse, a red giant star astronomers expectantly watch hoping for a spectacular supernova show, is 642 light years away – enough for an explosion to be visible in our daytime skies, but posing no harmful effects. We're lucky in that regard, because a local supernova could spell real trouble for us, damaging the atmosphere and bombarding us with radiation, likely triggering a mass extinction event.

"A LOCAL SUPERNOVA COULD SPELL REAL TROUBLE FOR US, BOMBARDING US WITH RADIATION"

7 ENCOUNTER WITH A HYPERVELOCITY STAR

Stars move at different speeds as they travel around our galaxy. For example, our Sun travels around the galactic centre at about 220 kilometres (137 miles) per second, completing an orbit in around 230 million years. But closer to the centre, orbits get a lot quicker. The very fastest stars beat the Sun's speed at least tenfold, achieving escape velocity and sometimes becoming unbound from the Milky Way. These so-called hypervelocity stars are thought to have been accelerated by close encounters with Sagittarius A*, our galaxy's supermassive black hole, or by a former binary partner going supernova.

Because of their immense speeds, these stars don't follow typical orbits and can make their own paths – it's also suspected that some may enter the Milky Way from dwarf galaxies like the Large Magellanic Cloud (LMC). It's highly improbable because of the vastness of space, but if a hypervelocity star passed too close to our Solar System on its way out, it could cause some serious disruption, either by disturbing the Oort Cloud and sending thousands of comets into the Solar System or destabilising the orbit of Earth itself.



© NASA/ESA

HOW HE 0437-5439 BECAME A LOOSE CANNON

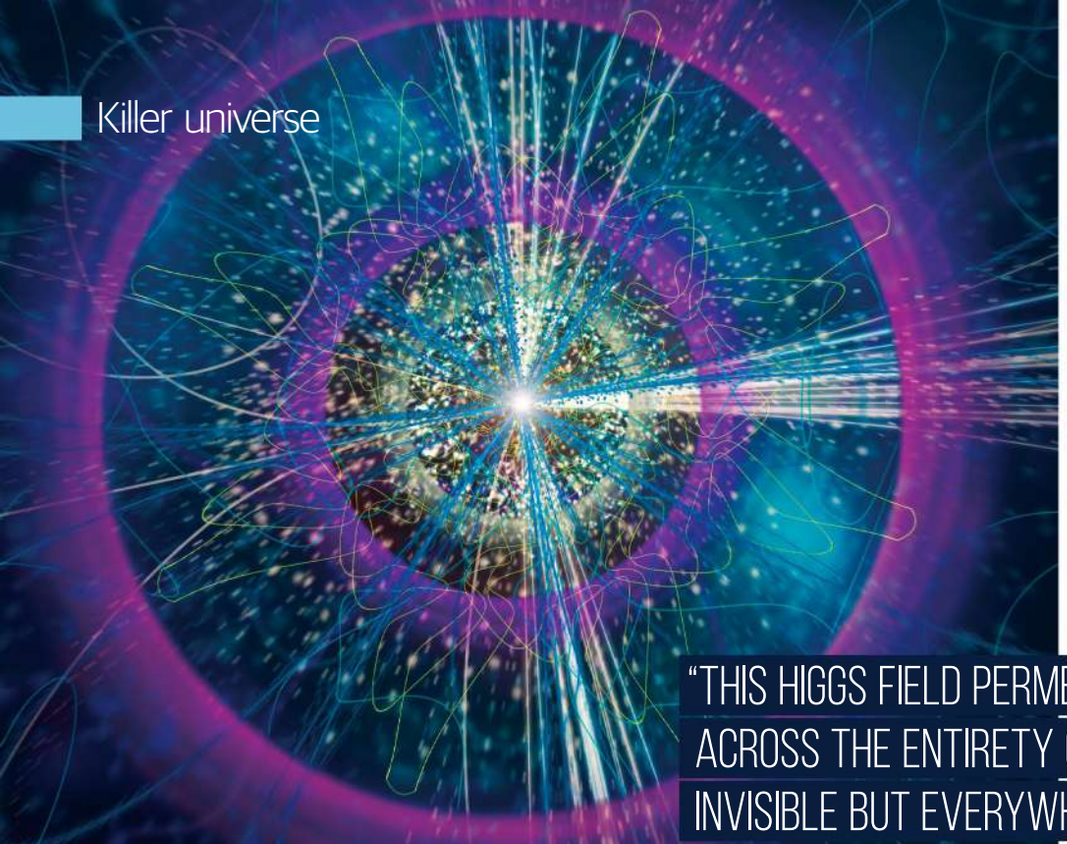
1 CUT LOOSE
About 100 million years ago, the star system's more distant component was pulled towards Sagittarius A*.

2 DANGEROUS ORBIT
The stellar triplets probably formed billions of years ago in an orbit close to the Milky Way's central black hole.

3 MERGING STARS
The heavier of the two surviving stars evolved more quickly, engulfing its partner, and the two merged.

4 OUT OF THE CORE
The close binary was flung towards intergalactic space fast enough to escape our galaxy's gravitational pull.

5 INTERGALACTIC REFUGEE
HE 0437-5439 is now 200,000 light years from the core or our galaxy, headed for a close approach with the LMC.



"THIS HIGGS FIELD PERMEATES ACROSS THE ENTIRETY OF SPACE, INVISIBLE BUT EVERYWHERE."

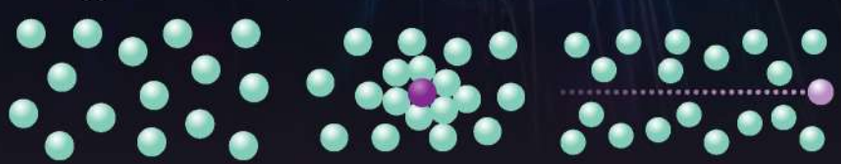
8 A CHANGING HIGGS FIELD

A subatomic particle confirmed at the Large Hadron Collider in 2012, the Higgs boson, along with the associated Higgs field, is what gives every particle in the universe mass. This Higgs field permeates across the entirety of space, invisible but everywhere. A particle which moves through this field with ease, like a neutrino, has a lower mass than one which encounters more resistance. But the Higgs' own mass is capable of changing, and that would alter the very universe through the strength of the Higgs field. The field is understood to be metastable, unchanging, but potentially not at its lowest possible energy level, meaning we currently exist in a false vacuum.

It would only take a single Higgs boson somewhere in the universe collapsing to a lower energy state to change the mass of all subatomic particles and the very physics of the universe, triggering catastrophic vacuum decay. If this were to happen, a bubble of true vacuum could radiate outwards from the source at the speed of light at any time, and we wouldn't see it coming. We'd just be obliterated without warning, and the universe might never again have the right conditions to support life, or anything.

HIGGS: WHY MATTER HAS MASS

Particles may be more massive than one another because they feel the Higgs field differently



MEETING THE HIGGS FIELD

The Higgs field occurs everywhere and gives matter particles mass. We can envision the Higgs field as a group of evenly separated balls.

ENTER ORDINARY MATTER

When a particle of ordinary matter moves through the Higgs field, the field becomes excited and forms Higgs bosons, which cluster around the particle and provide it with mass.

HIGH-SPEED PHOTONS

Particles can move through space without interacting with the Higgs field. They don't gain any mass from Higgs bosons and remain massless. A photon is one such particle.

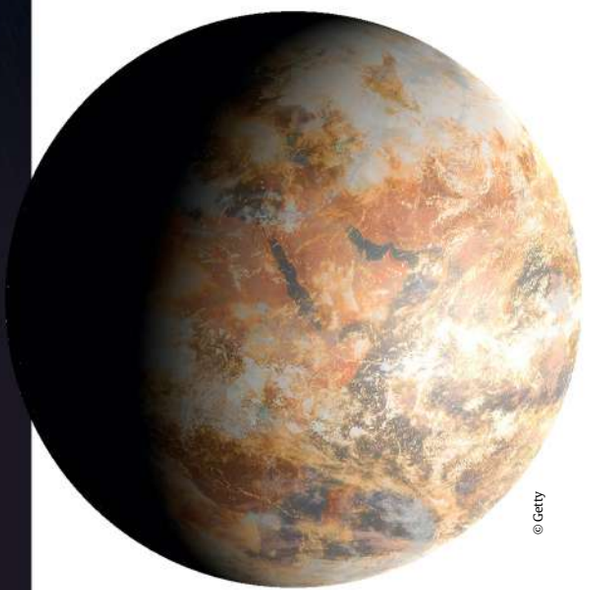
© Tobias Roetsch

9 LOSS OF EARTH'S MAGNETIC FIELD

As well as our atmosphere acting as an oxygen-filled shield, Earth's magnetic field plays a critical role in protecting our planet and all its inhabitants from the dangers of cosmic radiation, redirecting the solar wind and radiation from other sources away from the surface. The magnetosphere is a result of Earth's rotation – as molten iron-nickel swirls around the solid inner core, a giant dynamo is created, powering this global field. But it's in a constant state of flux, with its strength varying over time. It also appears to be cooling, which spells trouble for the future of our planet. A weaker magnetic field isn't able to protect us from radiation that well, meaning we'd be under threat by any high doses sent our way by solar events like flares and coronal mass ejections, or from more distant high-energy events. The constant bombardment of the solar wind could also affect our atmosphere, stripping away our planetary protection even further. In fact, many scientists believe this is how Mars ended up as a desolate dust ball. Perhaps we await the same destiny.

Left: The Higgs boson is an elementary particle

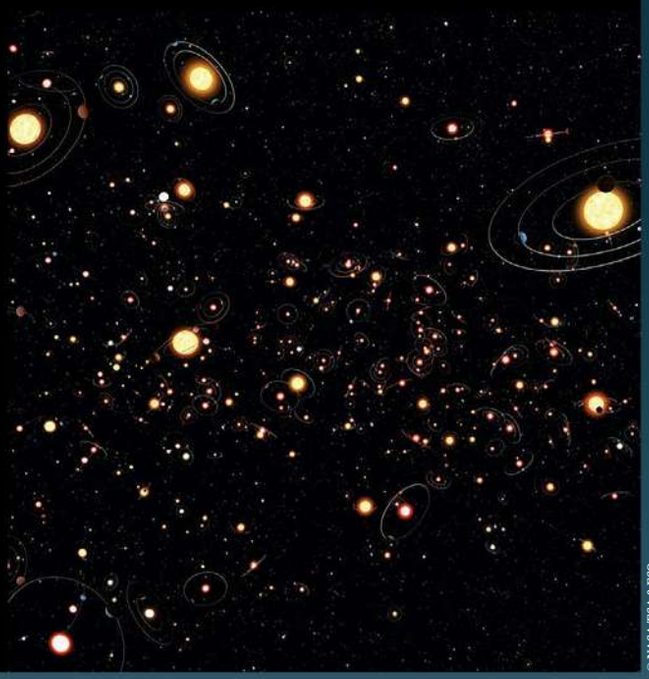
Below: A waterless, dead Earth would be much more Martian



© Getty

10 WE'RE NOT PAST THE GREAT FILTER

While aliens seeking us out could end badly, finding even simple signs of life in the universe could also be problematic. It's estimated our galaxy hosts 100 billion planets, so why haven't we found any with signs of life? It's been posited that there may be filters along the evolutionary scale that prevent life from reaching certain stages, and that a 'Great Filter' prevents any species from reaching spacefaring status. The big question is whether we're past this point, or not. If we are, we could be the very first species to make it, explaining the silence of space. As the most advanced, intelligent species on our own planet, it's not too hard to imagine us being farther ahead going further afield. However, if this filter still lies ahead, humanity is doomed. Some hypothesise that the Great Filter could be a consequence of advancing technology, and that any species capable of developing its planet is also set to destroy itself, so perhaps we're already on this path to destruction.



© NASA/ESA & ESO

Above: Planets are widespread, so why haven't we found signs of life yet?

Below: We'd have no defence against advanced alien technology

11 HOSTILE ALIENS

While humanity has spent decades searching for alien signals and signs of life from elsewhere in the galaxy, there's a chance that extraterrestrials could find us first, with disastrous results. If an advanced civilisation were to drop in above our planet unexpectedly, it's likely that their technology would be much more advanced than ours, including weaponry. As famously said by physicist Steven Hawking: "Such advanced aliens would perhaps become nomads, looking to conquer and colonise whatever planets they can reach." If these visitors had bad intentions – or if they were to deem us a threat to the galaxy – they could destroy us all with harmful technology that humanity hasn't even imagined yet. They may also want to harvest our planet's resources for themselves, or be looking for a new habitable home after having to leave their own world.

© Getty

Focus on

VERY LARGE TELESCOPE FINDS NEW SUPERMASSIVE BLACK HOLE

Scientists spotted the supermassive black hole hiding inside thick cosmic dust

Reported by Samantha Mathewson

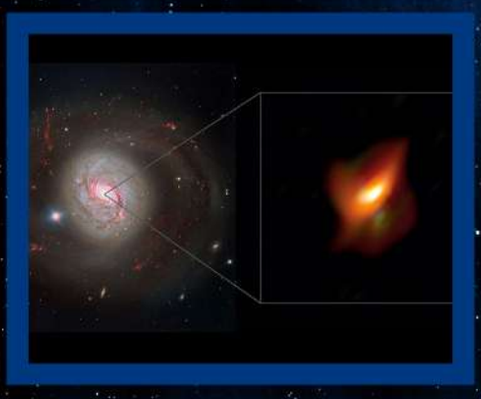
A supermassive black hole masked by a cloud of cosmic dust was found at the centre of an active galaxy in new images from the European Southern Observatory (ESO). The galaxy, known as Messier 77 or NGC 1068, is a barred spiral galaxy located about 47 million light years from Earth in the constellation of Cetus. Taken by the ESO's Very Large Telescope Interferometer (VLTI) in northern Chile, the observations shed new light on galaxies that have active galactic nuclei (AGN) at their core. These bright features are fuelled by all the gas and dust that falls into the galaxy's central black hole, causing the area to outshine the rest of the galaxy.

"Our results should lead to a better understanding of the inner workings of AGN," said Violeta Gámez Rosas from Leiden University in The Netherlands. "They could also help us better understand the history of the Milky Way, which harbours a supermassive black hole at its centre that may have been active in the past."

The recent image, taken using the Multi-AperTure mid-Infrared SpectroScopic Experiment (MATISSE) mounted on ESO's VLTI, revealed a thick ring of cosmic dust and gas concealing a supermassive black hole at the galaxy's core. The findings support a principle called the Unified Model of AGN, which holds that all AGN have the same structure, but may look different based on how they are viewed from Earth. "The real nature of the dust clouds and their role in both feeding the black hole and determining how it looks when viewed from Earth have been central questions in AGN studies over the last three decades," Gámez Rosas said in a statement. "While no single result will settle all the questions we have, we have taken a major step in understanding how AGN work."

The brightness of AGN varies depending on how much light from the central black hole is obscured by surrounding dust and gas. In this case, Messier 77 appears more subdued than other AGN because the thick ring of dust and gas completely hides the black hole from our view. However, the MATISSE instrument can see a broad range of infrared wavelengths, allowing researchers to peer through the thick, dusty ring. With this technique, the team was able to measure differences in the temperature of the dust caused by radiation from the black hole, as well as absorption of the dust clouds around the black hole. This in turn allowed the scientists to pinpoint the location of the black hole in Messier 77.

Data from the Atacama Large Millimeter/submillimeter Array (ALMA) and the National Radio Astronomy Observatory's Very Long Baseline Array was also used to create the new detailed view of Messier 77. "Messier 77 is an important prototype AGN and a wonderful motivation to expand our observing program and to optimise MATISSE to tackle a wider sample of AGN," Bruno Lopez, MATISSE principal investigator at the Observatoire de la Côte d'Azur in Nice, France, said.



© ESO

Left: Precise instruments were able to peer past the dust and gas that obscured the black hole

© Getty

THE BIGGEST EYES ON THE SKY

Alongside the Very Large Telescope (VLT), the Extremely Large Telescope (ELT) will investigate supermassive black holes

1 ARC DE TRIOMPHE, PARIS

One of the most famous monuments in Paris, the Arc de Triomphe stands at 50 metres (164 feet) tall, shorter than the ELT.

2 ELT, CHILE

The largest telescope ever constructed, the ELT exterior dome will reach 74 metres (243 feet). The dome has a diameter of about 86 metres (282 feet).

3 THE LONDON EYE, UK

At 135 metres (443 feet), the Eye towers over the Extremely Large Telescope by a massive 61 metres (200 feet).

4 VLT, CHILE

The Very Large Telescope at Paranal Observatory is dwarfed by the ELT, barely scraping 30 metres (98 feet).

5 STATUE OF LIBERTY, NEW YORK

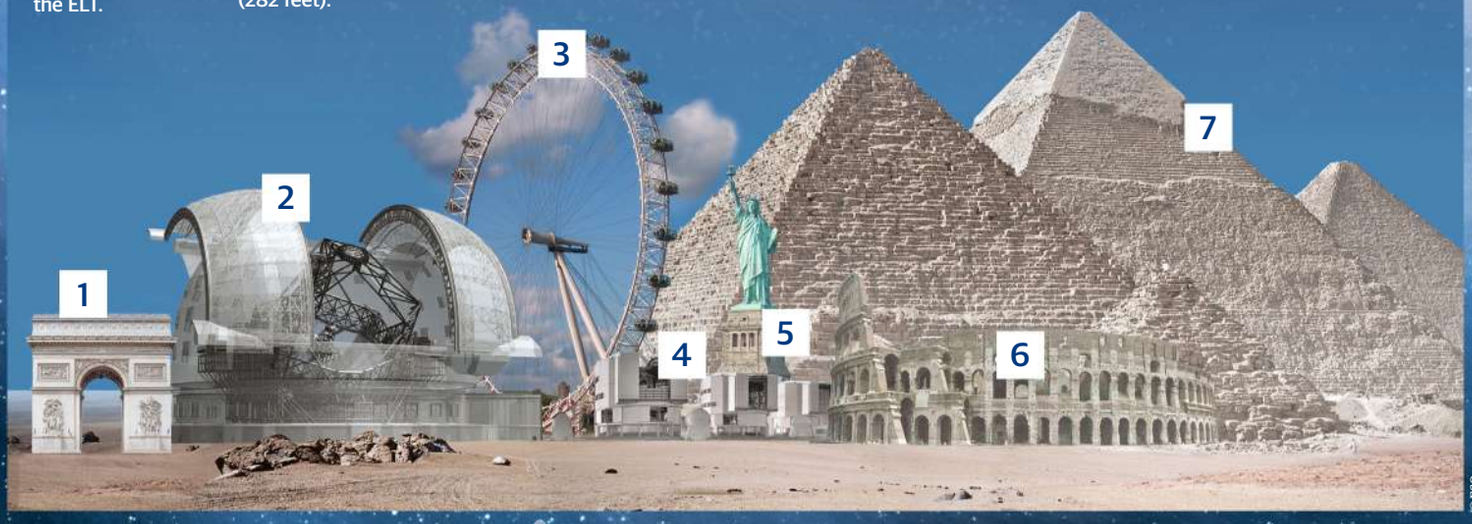
Lady Liberty is 93 metres (305 feet) from the ground to her torch, roughly the same as a 22-storey building.

6 THE COLOSSEUM, ROME

The Colosseum remains fearsome, but at 48 metres (157 feet) it's just over half the height of the ELT.

7 GREAT PYRAMID OF GIZA

The ELT is dwarfed by the Great Pyramid of Giza, standing at an impressive 138 metres (452 feet).



© ESO

HOW MANY STARS ARE THERE IN THE UNIVERSE?

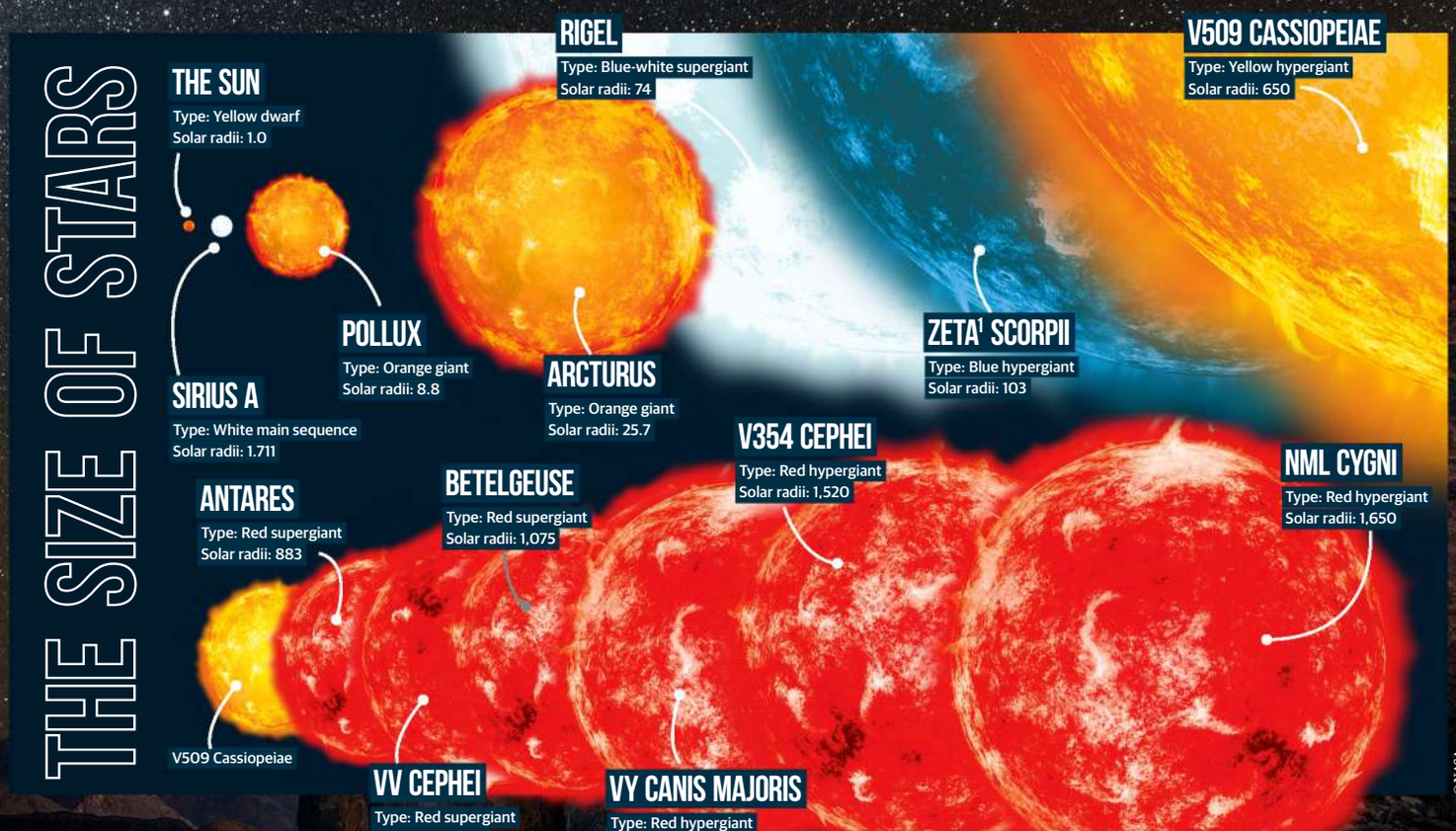
WITH A FLEET OF MISSIONS SCOURING THE COSMOS, WILL IT EVER BE POSSIBLE TO COME TO AN ESTIMATE?

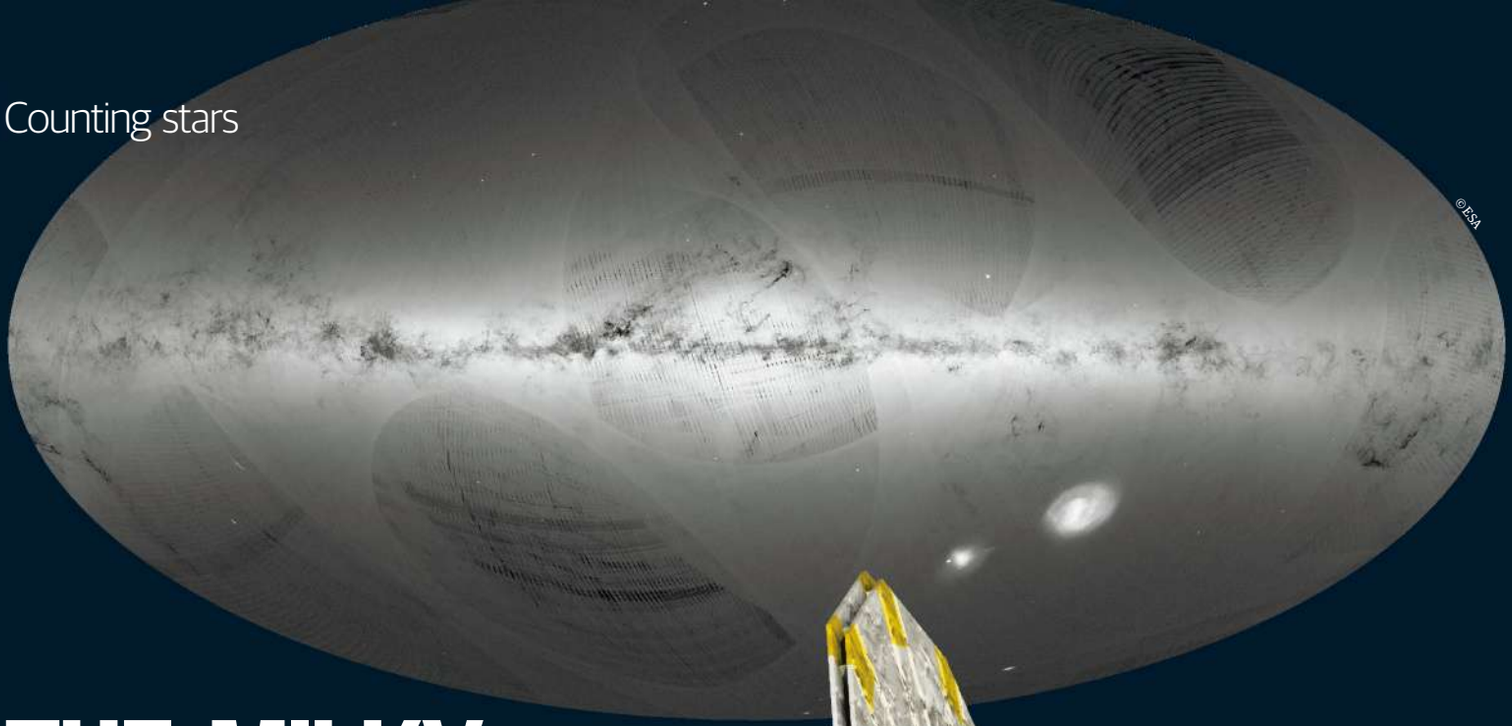
Reported by Ailsa Harvey

Looking up into the night sky, you might wonder just how many stars are in the universe. It's challenging enough for an amateur astronomer to count the number of naked-eye stars that are visible, and with bigger telescopes, more stars come into view, making counting them a lengthy process. So how do astronomers figure out how many stars are in the universe?

The first tricky part is trying to define what 'universe' means, says David Kornreich, a professor at Ithaca College in New York State. He was also the founder of the 'Ask An Astronomer' service at Cornell University. "I don't know, because I don't know if the universe is infinitely large or not," he said. The observable universe appears to go back in time by about 13.8 billion years, but beyond what we could see there could be much more. Some astronomers also think that we may live in a 'multiverse', where there would be other universes like ours contained in some sort of larger entity.

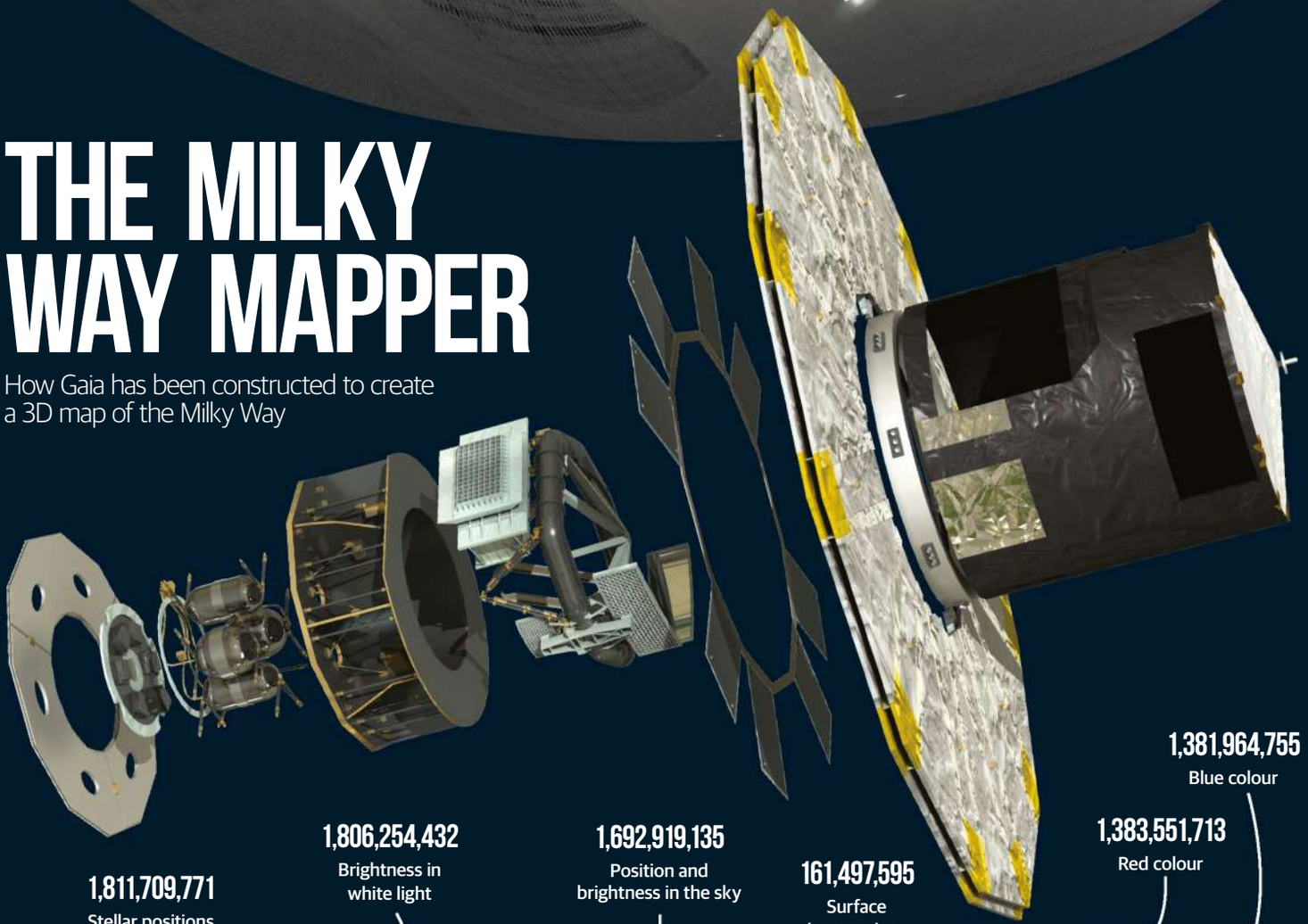
The simplest answer may be to estimate the number of stars in a typical galaxy, and then multiply that by the estimated number of galaxies in the universe. But even that is difficult, as some galaxies shine better in visible light or in infrared. There are also estimation hurdles that must be

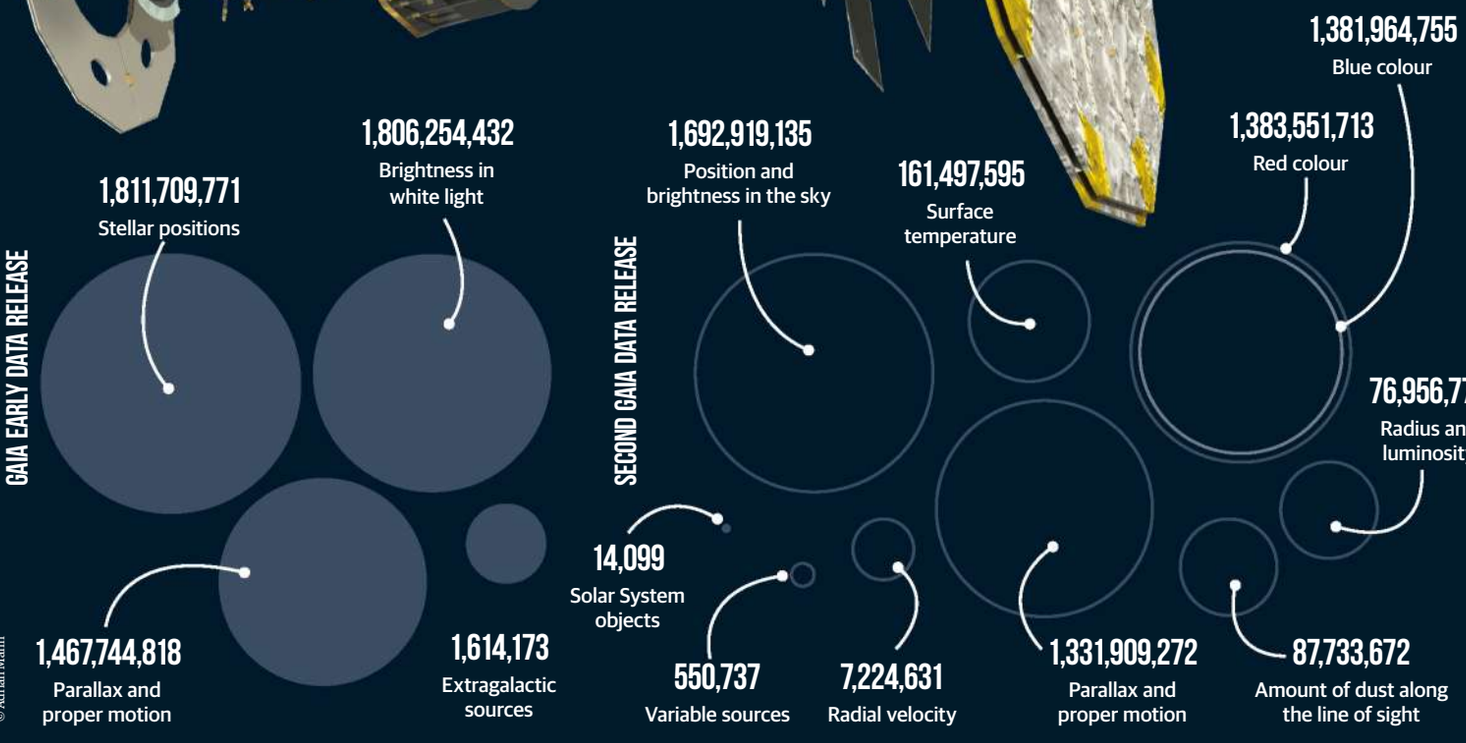




THE MILKY WAY MAPPER

How Gaia has been constructed to create a 3D map of the Milky Way





© Adrian Mann

1 NOT A SCORCHER
The sunshield keeps the scientific instruments at a constant temperature of -110 degrees Celsius (-166 degrees Fahrenheit). It has thermal insulation and is resistant to temperatures between -170 and 70 degrees Celsius (-274 and 158 degrees Fahrenheit).

2 SENSITIVE SENSORS
Gaia has sensors that are so powerful they can detect faint objects with a luminosity 400,000 times lower than the naked eye is capable of seeing.

3 STRONG SIGNAL
The average UK broadband speed is 14.7Mbps. While Gaia's 8.7Mbps may seem slow in comparison, considering it's beaming from 1.5 million kilometres (932,000 miles) away, it's quite good.

4 PACKING LIGHT?
Gaia's got some payload: ten mirrors, an astrometry function, a photometry function and a spectrometry function all within the one unit on a spacecraft three metres (9.8 feet) high.

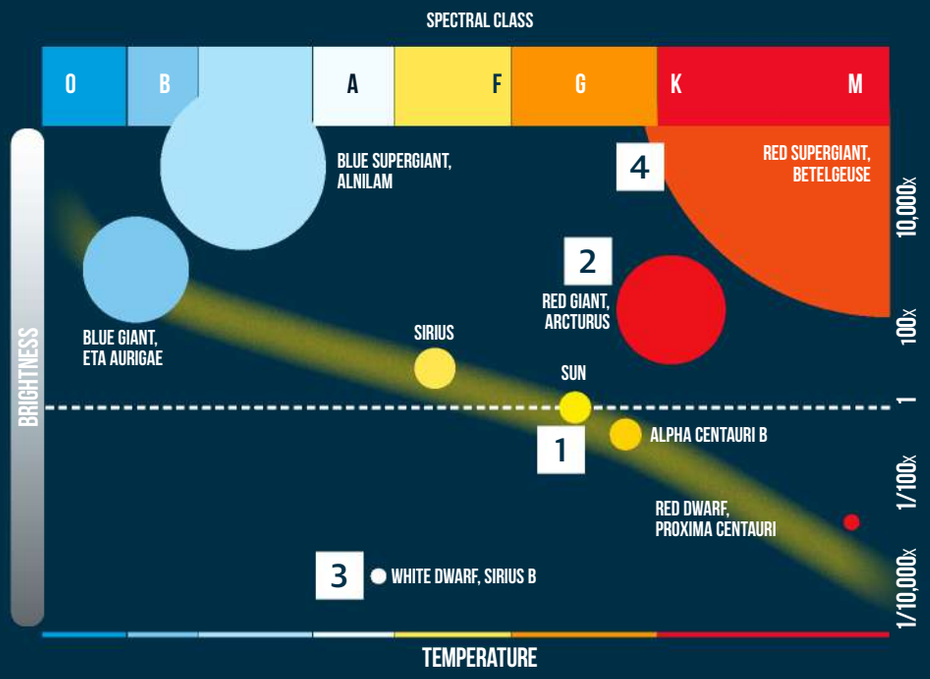
5 SNAP HAPPY
Chinese manufacturer Oppo may be creating a 50-megapixel smartphone camera, but Gaia boasts a photometer with a resolution of 1,000 megapixels. That's sharp.

6 DATA HUNGRY
So much data will be taken by Gaia that if you were to put everything onto a DVD, you would need 200,000 discs: that's more than 100 terabytes worth.

7 SILICON CARBIDE
The material that goes into making cutting tools and sandpaper is silicon carbide. It's tough stuff – a mix of pure silica sand and carbon – and it makes up Gaia's structure.

8 HUGE SUNSHIELD
A cutting-edge sunshield made from carbon-fibre-reinforced composite protects the Gaia spacecraft during its mission. It's like a big skirt at ten metres (33 feet) in diameter.

STAR CLASSIFICATION



1 MAIN SEQUENCE
This is the region where stars spend the majority of their lives – a star's position in the main sequence is largely determined by its mass.

2 RED GIANTS
Most stars pass through this phase near the end of their lives, brightening and developing an atmosphere with a cool surface.

3 WHITE DWARFS
These hot stars are faint because of their tiny size – they are the burnt-out, slowly cooling cores of stars like our own Sun.

4 SUPERGIANTS
Brilliantly luminous high-mass stars that display a variety of colours as they move back and forth across the Hertzsprung-Russell diagram.

overcome. In October 2016, deep-field images from the Hubble Space Telescope suggested that there are about 2 trillion galaxies in the observable universe, or about ten times more galaxies than previously suggested. Speaking with **All About Space**, the lead author of a new study published in *Nature*, Christopher Conselice, a professor of astrophysics at the University of Manchester in the UK, says there are about 100 million stars in the average galaxy.

Even telescopes may not be able to view all the stars in a galaxy, however. A 2008 estimate by the Sloan Digital Sky Survey - which catalogues all the observable objects in a third of the sky - found about 48 million stars, roughly half of what astronomers expected to see. A star like our own Sun may not even show up in such a catalogue, so many astronomers estimate the number of stars in a galaxy based on its mass. This has its own difficulties, since dark matter and galactic rotation must be filtered out before making an estimate.

Missions such as Gaia, a European Space Agency (ESA) probe that launched in 2013, may provide further answers. Gaia aims to precisely map about 1 billion stars in the Milky Way. It builds on the previous Hipparcos mission, which precisely located 100,000 stars and also mapped 1 million stars to a lesser precision.

"Gaia will monitor each of its 1 billion target stars 70 times during a five-year period, precisely charting their positions, distances, movements and changes in brightness," the ESA states on its website. "Combined, these measurements will build an unprecedented picture of the structure and evolution of our galaxy. Thanks to missions like these, we are one step closer to providing a more reliable estimate to a question asked so often: 'How many stars are there in the universe?'"

Even if we narrow down the definition to the 'observable' universe - just what we can see - estimating the number of stars within it requires knowing just how big the universe is. The first complication is that the universe itself is expanding, and the second complication is that space-time can curve.

© Getty

Above: The darker the sky, the more stars become visible

To take a simple example, light from the objects farthest away from us would take approximately 13.8 billion years to travel to Earth, taking into account that the very youngest objects would be shrouded because light couldn't carry in the early universe. The radius of the observable universe should be 13.8 billion light years, since light only has that long to reach us.

Or should it? "It's a logical way to define distance, but not how a relativist defines distance," Kornreich says. A relativist would use a device such as a metre stick, measuring the distance along that device and then extending it as long as needed. This produces a different answer, and some sources define the universe as being 48 billion light years in radius. But sources vary on this number because space-time can curve. As the observer does the measurement with the metre stick, light travels at the same time and influences the measurements.

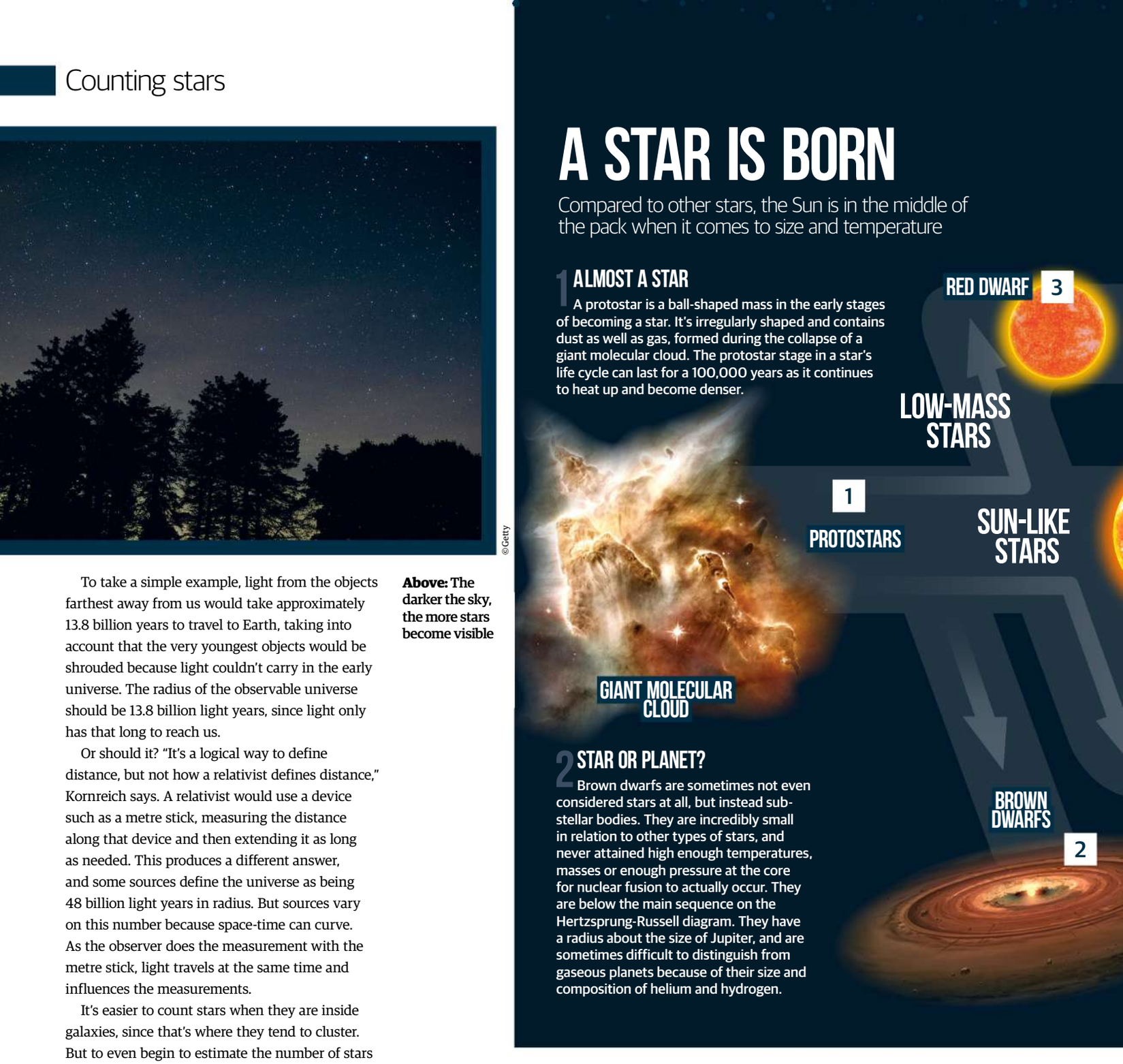
It's easier to count stars when they are inside galaxies, since that's where they tend to cluster. But to even begin to estimate the number of stars in the universe, you would need to estimate the number of galaxies and come up with some sort of an average, even though galaxies vary wildly.

Some estimates peg the Milky Way's star mass at around 100 billion solar masses, or 100 billion times the mass of the Sun. Averaging out the types of stars within our galaxy, this would produce an answer of about 100 billion stars in the galaxy. This is subject to change, however, depending on how many stars are bigger and smaller than our Sun. Other estimates say the Milky Way could have 200 billion stars or more.

The amount of galaxies that permeate the universe is an astonishing number, as shown by some imaging experiments performed by the Hubble Space Telescope. Several times over the years, Hubble has pointed a detector at a tiny spot in the sky to count galaxies, performing the work again after the telescope was upgraded by astronauts during the Space Shuttle era.

A 1995 exposure of a small spot in Ursa Major revealed about 3,000 faint galaxies. In 2003 to 2004, utilising Hubble's upgraded instruments, scientists looked at a smaller spot in the southern constellation of Fornax and found 10,000 galaxies. An even more detailed investigation in Fornax in 2012, with even better instruments, showed about 5,500 galaxies.

Kornreich uses a very rough estimate of 10 trillion galaxies in the universe. Multiplying that by the Milky Way's estimated 100 billion stars results in a large number indeed: 1^{24} stars, or a one with 24 zeros after it. That's 1 septillion in the American numbering system or 1 quadrillion in the European system. Kornreich emphasises that number is likely a gross underestimation, as more detailed studies of the universe will reveal even more galaxies.


A STAR IS BORN
Compared to other stars, the Sun is in the middle of the pack when it comes to size and temperature
1 ALMOST A STAR
A protostar is a ball-shaped mass in the early stages of becoming a star. It's irregularly shaped and contains dust as well as gas, formed during the collapse of a giant molecular cloud. The protostar stage in a star's life cycle can last for a 100,000 years as it continues to heat up and become denser.
RED DWARF
3
LOW-MASS STARS
1
PROTOSTARS
SUN-LIKE STARS
GIANT MOLECULAR CLOUD
2 STAR OR PLANET?
Brown dwarfs are sometimes not even considered stars at all, but instead sub-stellar bodies. They are incredibly small in relation to other types of stars, and never attained high enough temperatures, masses or enough pressure at the core for nuclear fusion to actually occur. They are below the main sequence on the Hertzsprung-Russell diagram. They have a radius about the size of Jupiter, and are sometimes difficult to distinguish from gaseous planets because of their size and composition of helium and hydrogen.
BROWN DWARFS
2

Ailsa Harvey
Science and technology journalist
Ailsa is a staff writer for **How It Works** magazine, where she focuses on writing about science, technology, history and the environment.

3 THE COOL STAR

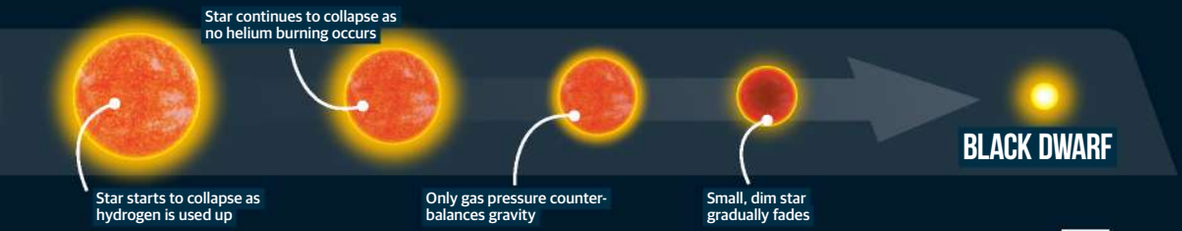
Red dwarfs are small and relatively cool, tending to have masses less than one-half that of our Sun. The heat generated by a red dwarf occurs at a slow rate through the nuclear fusion of hydrogen into helium before being transported via convection to its surface.

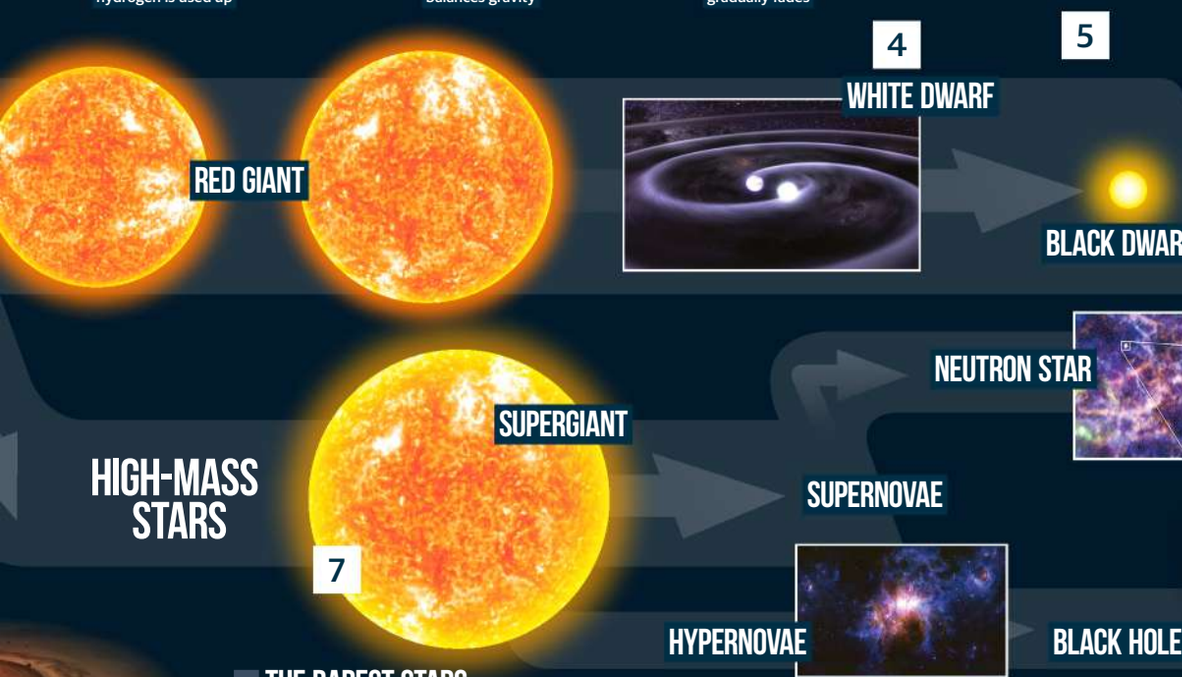
4 A DEAD STAR

White dwarfs are the end of a small star's life cycle. A white dwarf is small, with a volume comparable to that of Earth's, but incredibly dense, with a mass about that of the Sun's. With no energy left, a white dwarf is dim and cool in comparison to larger stars.

5 STELLAR REMNANTS

Black dwarfs are the hypothetical next stage of star degeneration, when they become sufficiently cool to no longer emit any heat or light. Because the time required for a white dwarf to reach this state is postulated to be longer than the current age of the universe, none are expected to exist yet. If one were to exist it would be difficult to locate and image due to the lack of emitted radiation.


Star continues to collapse as no helium burning occurs
Star starts to collapse as hydrogen is used up
Only gas pressure counter-balances gravity
Small, dim star gradually fades
BLACK DWARF



6 NEUTRON STARS

Neutron stars are a potential next stage in the life cycle of a star. If the mass that remains after a supernova is up to three times that of the Sun, it becomes a neutron star. This means that the star only consists of neutrons, particles that don't carry an electrical charge.

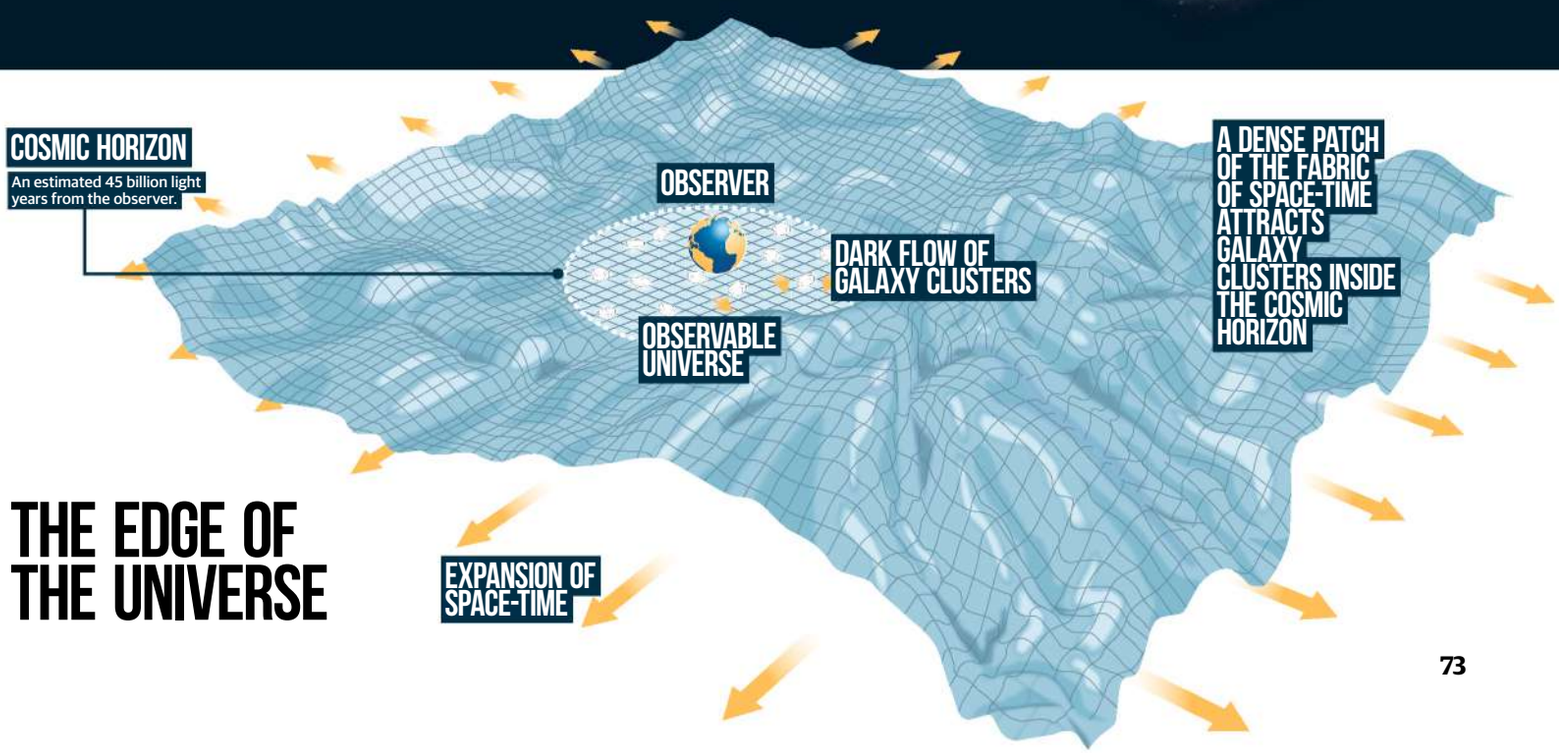
7 THE RAREST STARS

Supergiants are among the rarest stars, and can be as large as our entire Solar System. Supergiants can also be tens of thousands of times brighter than the Sun and have radii of up to a thousand times that of the Sun.

8 THE ABSENCE OF LIGHT

Stellar black holes are thought to be the end of the life cycle for supergiant stars with masses more than three times that of our Sun. After going supernova, some of these stars leave remnants so heavy that they continue to remain gravitationally unstable.

©NASA


COSMIC HORIZON
An estimated 45 billion light years from the observer.
OBSERVER
DARK FLOW OF GALAXY CLUSTERS
OBSERVABLE UNIVERSE
A DENSE PATCH OF THE FABRIC OF SPACE-TIME ATTRACTS GALAXY CLUSTERS INSIDE THE COSMIC HORIZON
EXPANSION OF SPACE-TIME

THE EDGE OF THE UNIVERSE

ASK Space

Our experts answer your questions

ASTROPHYSICS

How do black holes form?

Most black holes form when a massive star exhausts its fuel supply and collapses. But the origins of the largest black holes remain mysterious. There are two very different types of black holes in the universe: stellar-mass black holes and supermassive black holes. Stellar-mass black holes are much more common, and usually weigh in at about 5 to 100 times the mass of the Sun. These form when a massive star fuses all of the material in its core into iron and can no longer provide additional energy to support its immense weight against gravity. The star then begins to collapse. Sometimes this triggers a supernova explosion that destroys the star, but if this explosion fails the collapse continues until the star is crushed down into a black hole.

Supermassive black holes are enormous: millions to billions of times the mass of the Sun. There's one in every large galaxy, right at the centre. We don't yet know how they got there. They may have formed directly from the collapse of huge gas clouds, or started as stellar-mass black holes that grew by swallowing material. Figuring out their origins is a major area of current research and one of the motivations for launching the James Webb Space Telescope.

Dr Daniel Perley, Astrophysics Research Institute, Liverpool John Moores University

Above: There are different types of black holes in the universe

© Getty

©Getty

SPACE EXPLORATION

Could we take a plane to space?

There are many reasons we can't just use an aircraft to get into space. A major one is that the higher up we go, the less air there is – or specifically the less 'oxygen' there is in the air. The engine is what helps the aircraft fly. And just like car engines, aircraft engines need oxygen to work. Aircraft suck air in at the front using big fans on either side. They then mix this air with jet fuel, creating a mixture of fuel and oxygen which is then burned, making the air hotter. The hot air is then shot out the back at a very high speed, pushing the aircraft forward. But an aircraft trying to fly too close to space, where there isn't enough oxygen, would be like a person trying to breathe in a room with no air in it. This is why we need rockets to get to space. The big difference between rocket engines and jet engines used in aircraft is rocket engines do not need to get oxygen from the air. Instead, they carry their own oxygen with them.

Dr Chris James, ARC DECRA fellow, Centre for Hypersonics, School of Mechanical and Mining Engineering at the University of Queensland

Did you know?

The high-altitude Lockheed SR-71 Blackbird aircraft has reached heights of almost 26,000 metres.

Above: Planes can't fly in space as there's no oxygen

Right: Meteorites from Mars can tell us a lot about the Red Planet

©NASA

©Getty

SOLAR SYSTEM

What do Martian meteorites tell us about the Red Planet?

Meteorites from Mars tell us about the geology and history of the Red Planet without the cost of a space mission. Clues that they come from Mars include that they are young and formed from lava, something difficult to explain if they had originated from the asteroid belt. These rocks have been ejected from Mars by violent impacts of asteroids or comets. The impact and ejection process forms glass that contains captured gas with a chemistry that's identical to the atmosphere of Mars, as measured by the Viking landers in the 1970s. Radiation-based evidence of the timing of ejection, alongside similarities between some samples, reveals that there are groups of Martian meteorites, with each group related to an individual impact event. Martian meteorites have allowed us to optimise techniques for use on landers and rovers on the surface of Mars and in laboratories back on Earth. These naturally delivered and highly valuable samples are helping us prepare for Mars sample return.

Mark Sephton, professor of organic geochemistry, Imperial College London

© Getty

SOLAR SYSTEM

Where did the word 'moon' come from?

Earth has just one moon. It's best known as the Moon in the English-speaking world because people in ancient times used the Moon to measure the passing of the months. The word 'moon' can be traced to the word mōna – an Old English word. Mōna shares its origins with the Latin words metri, which means to measure, and mensis, which means month. We see that the Moon is called the Moon because it is used to measure the months. But why do the moons around other planets have names, while ours is just the Moon?

When the Moon was named, people only knew about our Moon. That all changed in 1610 when Italian astronomer Galileo Galilei discovered what we now know are the four largest moons of Jupiter. Other astronomers discovered five moons around Saturn during the 1600s.

These objects became known as moons because they were close to their planets, just as our Moon is close to Earth. It's fair to say that other moons are named after our Moon. The newly discovered moons were given beautiful names to identify them among the growing number of planets and moons astronomers were finding in the Solar System.

Dr Toby Brown, Herzberg Institute of Astrophysics

© Tobias Roetsch

Above left: The Moon's appearance changes as each month passes

Above right: Saturn's ring particles are mostly made up of water ice

SOLAR SYSTEM

How do you find out what a planet's rings are made of?

We can start to get an idea of what these particles are made of by working out how big they are and how heavy they are. One way of doing this is with a technique called radio occultation. Objects in space with changing magnetic fields – such as planets or even space satellites – produce radio waves. As they pass through the rings around planets, these radio signals are affected in different ways by the particles in the ring, depending on the size of the particles and how heavy they are.

We can also measure how reflective the particles are to help work out what they are made of and what state they are in, such as whether they are liquid or solid. Ice is more reflective than water, and snow is extremely reflective – more so than ice or water. Thanks to measurements like this, we know that Saturn's ring particles are mostly made up of water ice. Jupiter's ring system is made up of fine dust particles, but these are not water-ice particles like Saturn. Instead the particles are likely to be rocky, made up of similar materials as asteroids and rocky moons. Although what Uranus' rings are made of is still unknown, they are dark and not very reflective. Neptune's rings are even darker than those of Uranus, and the density suggests that they are made of even finer dust. This is likely to be some kind of carbon or a source of carbon such as methane ice.

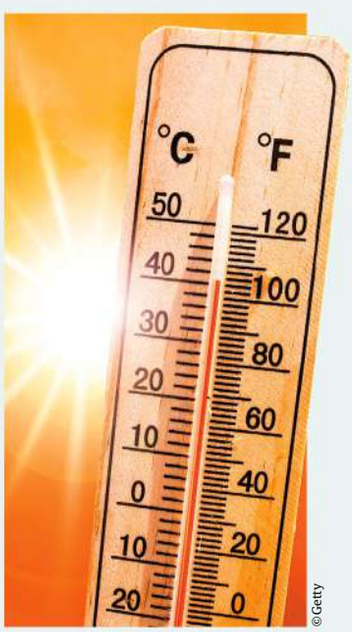
Dr Maggie Lieu, research fellow, University of Nottingham

ASTROPHYSICS

How do you measure the temperature in space?

For some nearby planets like Mars, we can send probes to study the atmosphere directly from the planet's surface. However, we haven't been able to do this for distant planets such as Neptune and Uranus. Instead we have to work out how cold they are by measuring their temperature from Earth. We do this by studying the light from the planet, which can tell us the types of atoms and molecules which make up the atmosphere. This lets us know exactly what the temperature of the planet is: the atoms and molecules act as a kind of temperature 'fingerprint' for the planet. While these planets are incredibly cold, there are even chillier places in the universe. The coldest of all is the Boomerang Nebula, a cloud of dust and gas 5,000 light years away from us. There, the temperature reaches -272 degrees Celsius (-457 degrees Fahrenheit). Nothing in the universe can be colder than -273 degrees Celsius (-459 degrees Fahrenheit), because at that temperature the tiny particles and atoms that everything is made of basically stop moving, and once that happens it's impossible to go colder. This temperature is known as absolute zero. This means it's unlikely that we will ever find anywhere in the universe colder than the Boomerang Nebula.

Brad Gibson, University of Hull



© Getty

Right: Nothing in the universe can be colder than absolute zero

ASTROPHYSICS

Could we ever prove that wormholes exist?

We don't know if wormholes exist, but if they do, it's likely that one day we will find them. Traversable wormholes are unlikely to exist, since there are no known physical mechanisms that can create them or keep them open. A hypothesised form of matter with antigravity effects may keep wormholes open. However, no such exotic matter has ever been observed.

Despite the unlikely odds, some scientists are thinking of how to detect wormholes. Some wormholes are black hole 'mimickers' – they have a positive effective mass, which means they act like black holes. A wormhole may bend the light from a star by passing in front of it in an effect called gravitational microlensing. Other wormholes may have an accretion disc, like supermassive black holes. The light from this disc can encode information about the space-time distortion around the wormhole, which may be different than around a black hole.

It may also become possible to image the shadow of a wormhole directly, just as it was done recently for the black hole in Messier 87. Wormholes may stand out by having differently shaped shadows. The detection of gravitational waves from a black hole merging with a wormhole could also be within reach of next-generation gravitational observatories.

Dr Andreea Font, reader in theoretical astrophysics, Liverpool John Moores University

Below: We might never find one

Did you know?

A wormhole is also called an Einstein-Rosen bridge, and they are consistent with the general theory of relativity.

© Getty

WHAT'S IN THE SKY?

IN THIS ISSUE...

78 What's in the sky?
The nights might lighten, but there's still plenty to see from dusk until dawn

82 Month's planets
A planetary parade is something spectacular to look out for in the dawn sky

84 Moon tour
Finding the fascinating crater called Hell isn't as hard as its name suggests

85 Naked eye and binocular targets
The early spring sky offers bright stars

86 Deep sky challenge
Spring has arrived, and with it a wealth of deep-sky objects in the heavens

88 The Northern Hemisphere
Spring lets you look out of the plane of the Milky Way

90 Astroshots of the month
The best of our readers' astrophotography

92 Binocular review
We put the Canon 10x42L IS WP binocular to the test

96 In the shops
The latest books, apps, tech, software and accessories

"THE MOON WILL PASS IN FRONT OF URANUS IN AN OCCULTATION IN ARIES"

RED-LIGHT FRIENDLY
In order to preserve your night vision, you should read our observing guide under red light

28 MAR
Conjunction between the Moon and Mars in Capricornus

©NASA/ESA

28 MAR
Conjunction between the Moon and Venus in Capricornus

28 MAR
The Moon and Mars make a close approach, within 3°55' of each other in Capricornus

28 MAR
Dwarf planet Makemake reaches opposition in Coma Berenices at +17.2

29 MAR
Venus and Saturn make a close approach, within 2°06' of each other in Capricornus

3 APR
Conjunction between Venus and Mars in Capricornus

5 APR
Spiral galaxy Messier 94 is well placed for observation in Canes Venatici

©NASA/ESA

©NASA/ESA

15 APR
The Whirlpool Galaxy (Messier 51) is well placed for observation in Canes Venatici

18 APR
Globular cluster Messier 3 is well placed for observation in Canes Venatici

JARGON BUSTER

CONJUNCTION

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

RIGHT ASCENSION (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

DECLINATION (DEC)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

MAGNITUDE

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

OPPOSITION

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

GREATEST ELONGATION

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

28 MAR
Conjunction between the Moon and Saturn in Capricornus

28 MAR
The Moon and Venus make a close approach, within 6°19' of each other in Capricornus

28 MAR
The Moon and Saturn make a close approach, within 4°11' of each other in Capricornus

29 MAR
Conjunction between Venus and Saturn in Capricornus

1 APR
The Sombrero Galaxy (Messier 104) is well placed for observation, glowing at +8.0

3 APR
The Moon will pass in front of Uranus in an occultation in Aries

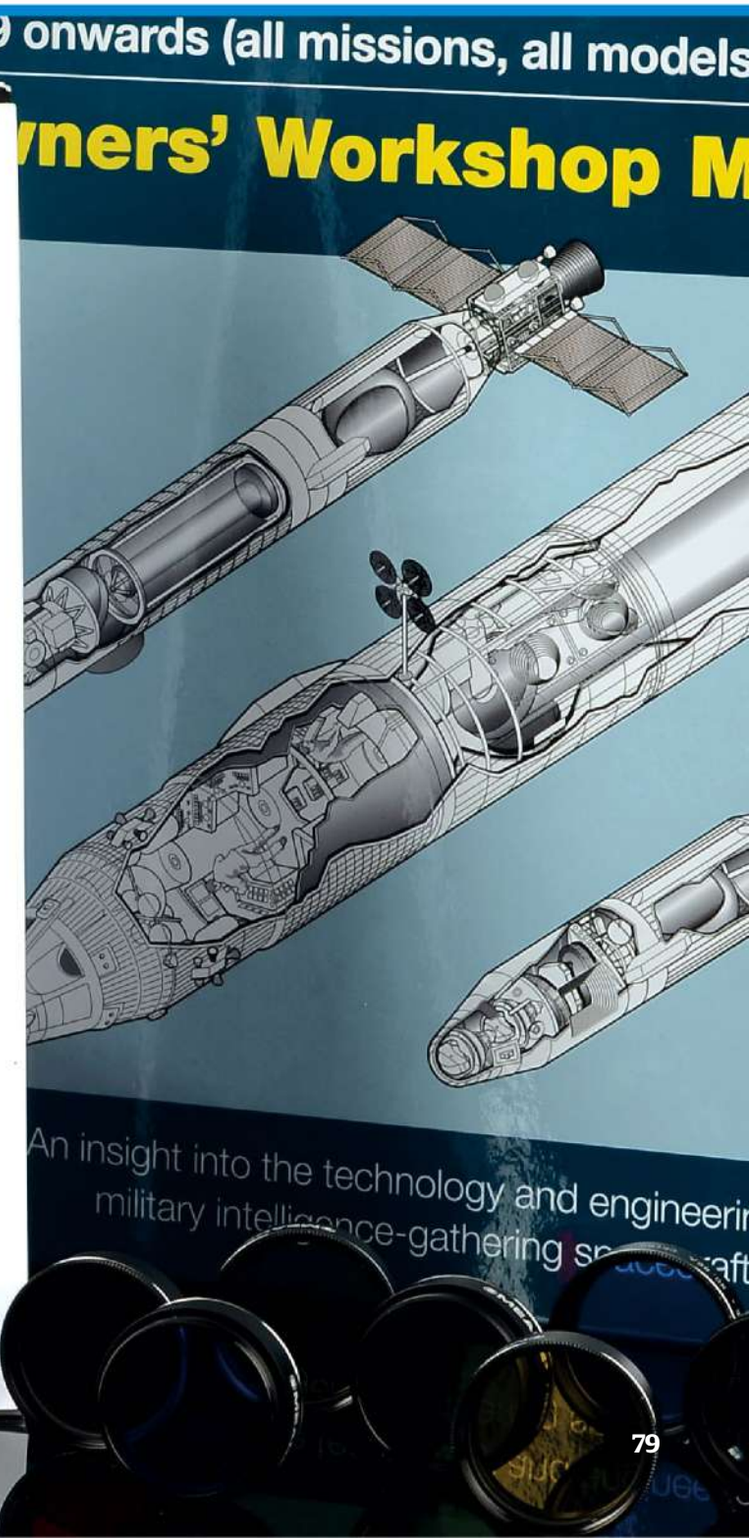
©NASA and the Hubble Heritage Team

5 APR
Saturn and Mars make a close approach, within 18.4 arcminutes of each other in Capricornus

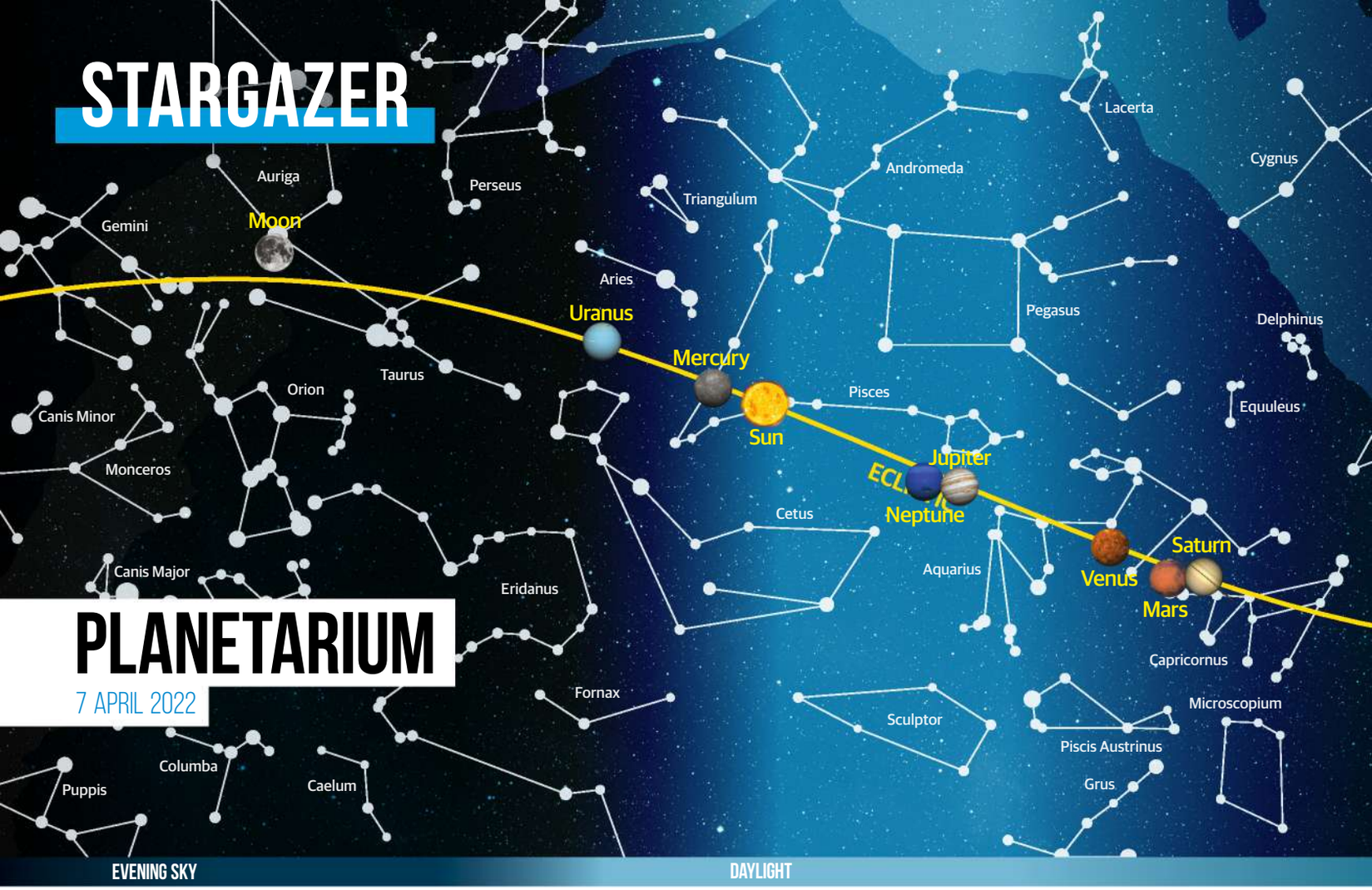
19 APR
Dwarf planet Haumea reaches opposition in Boötes

©NASA

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope


1959 onwards (all missions, all models
ners' Workshop M
An insight into the technology and engineeri
military intelli nce-gathering sp

STARGAZER



PLANETARIUM

7 APRIL 2022

MOON CALENDAR

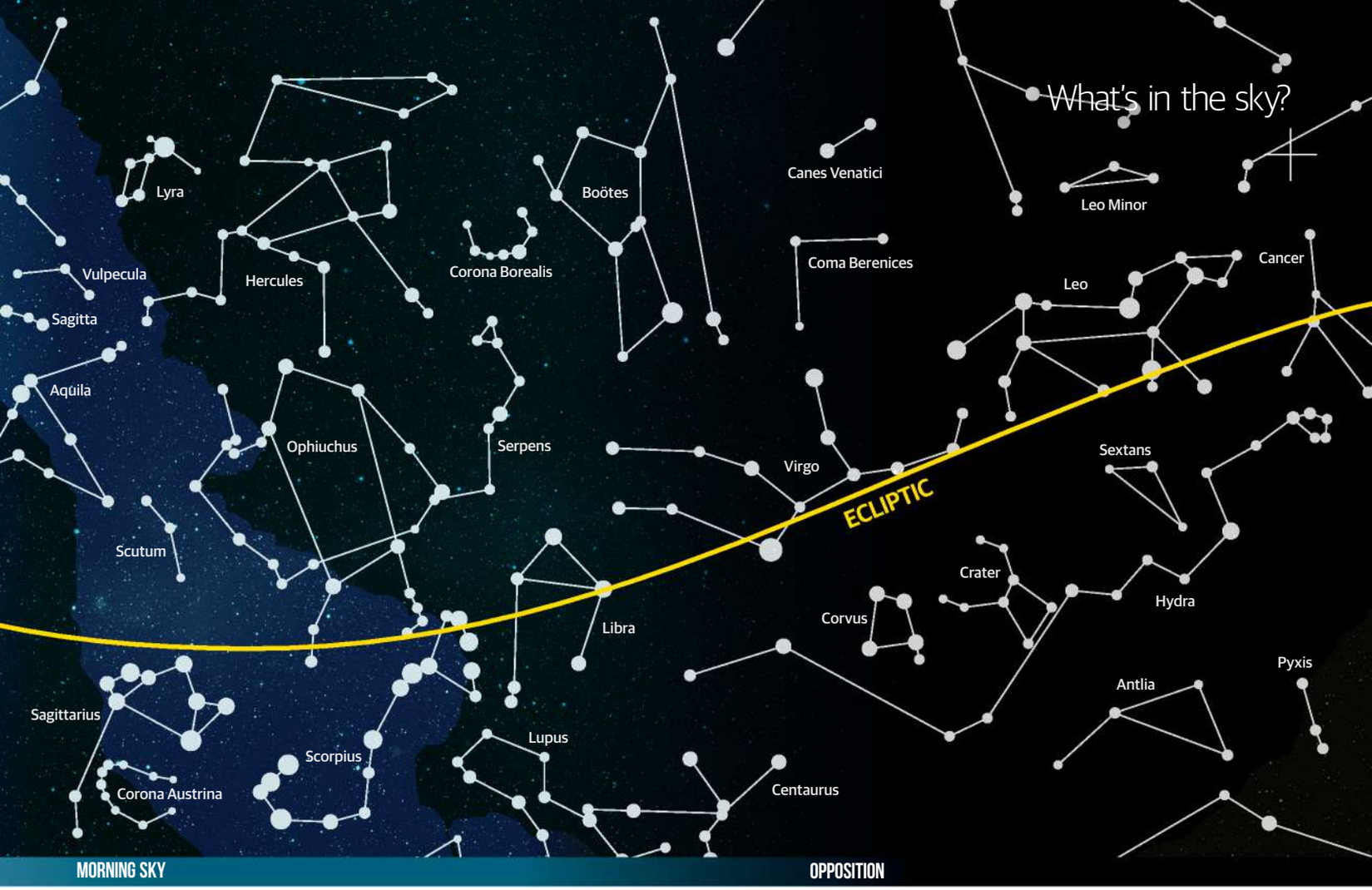
* The Moon does not pass the meridian on 15 April

24 MAR 61.7% 01:26 08:48	25 MAR TQ 49.9% 02:40 09:41	26 MAR 38.0% 03:40 10:49	27 MAR 27.0% 05:24 13:09			
28 MAR 17.3% 05:55 14:33	29 MAR 9.5% 06:17 15:57	30 MAR 4.0% 06:35 17:18	31 MAR 0.8% 06:49 18:37	1 APR NM 0.1% 07:03 19:53	2 APR 1.8% 07:16 21:09	3 APR 5.6% 07:31 22:23
4 APR 11.1% 07:47 23:37	5 APR 18.2% 08:08 --:--	6 APR 26.4% 00:49 08:34	7 APR 35.4% 01:56 09:09	8 APR 45.0% 02:55 09:54	9 APR FQ 54.9% 03:43 10:51	10 APR 64.6% 04:20 11:57
11 APR 74.0% 04:49 13:10	12 APR 82.6% 05:11 14:25	13 APR 90.0% 05:28 15:43	14 APR 95.6% 05:44 17:01	15 APR --:--%* 05:58 18:22	16 APR FM 99.1% 06:12 19:45	17 APR 99.9% 06:27 21:12
18 APR 97.9% 06:46 22:41	19 APR 93.0% 07:11 --:--	20 APR 85.4% 00:10 07:45	21 APR 75.7% 01:31 08:34			

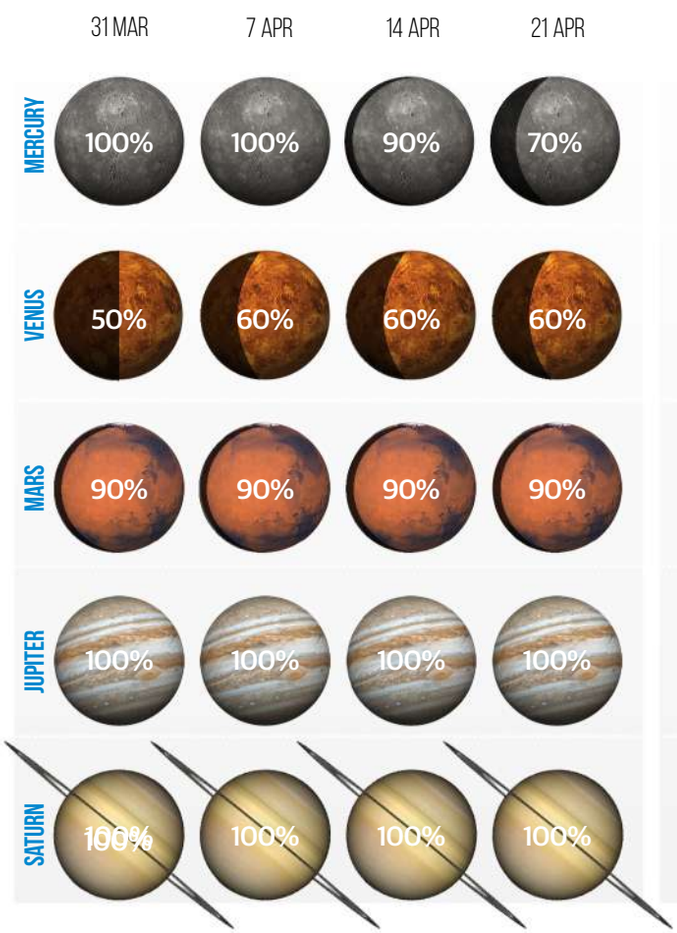
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

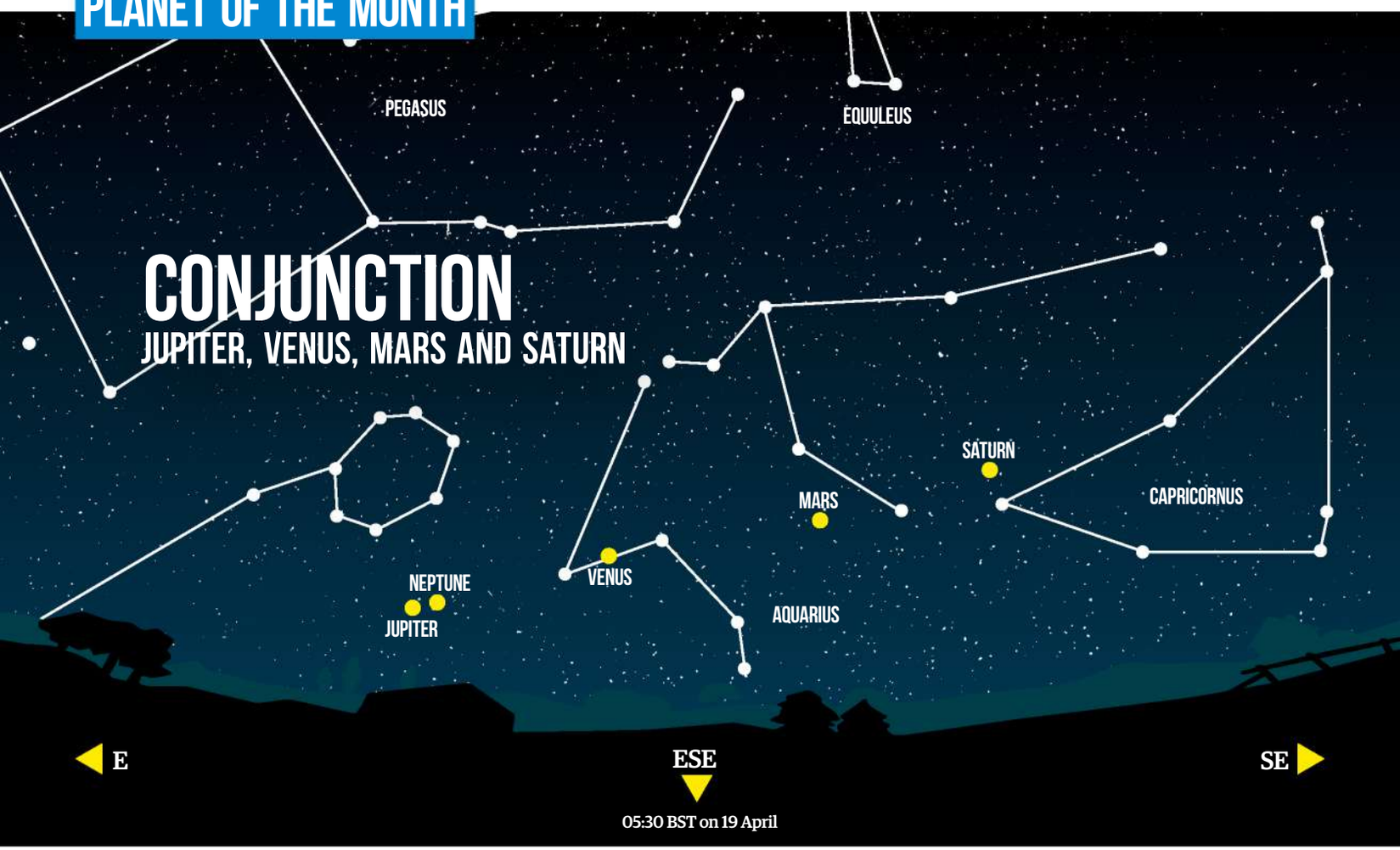
All rise and set times are given in GMT/BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
24 MAR	23h 39m 07s	-04° 28' 39"	Aquarius	-1.0	05:58	17:15
31 MAR	00h 27m 32s	+01° 25' 37"	Cetus	-1.8	06:45	19:09
7 APR	01h 19m 00s	+07° 54' 08"	Pisces	-1.9	06:32	20:10
14 APR	02h 11m 52s	+14° 12' 09"	Aries	-1.3	06:18	21:15
21 APR	03h 00m 50s	+19° 13' 28"	Aries	-0.8	06:04	22:11
24 MAR	21h 13m 45s	-14° 18' 14"	Aquarius	-4.4	04:32	13:51
31 MAR	21h 42m 50s	-12° 42' 12"	Capricornus	-4.3	05:24	15:03
7 APR	22h 12m 17s	-10° 45' 29"	Aquarius	-4.3	05:13	15:16
14 APR	22h 41m 52s	-08° 30' 31"	Aquarius	-4.2	05:02	15:32
21 APR	23h 11m 31s	-06° 00' 06"	Aquarius	-4.2	04:49	15:49
24 MAR	21h 03m 08s	-17° 59' 10"	Capricornus	+1.1	04:46	13:16
31 MAR	21h 24m 20s	-16° 29' 45"	Capricornus	+1.1	05:30	14:20
7 APR	21h 45m 14s	-14° 52' 43"	Capricornus	+1.0	05:12	14:24
14 APR	22h 05m 51s	-13° 09' 02"	Aquarius	+1.0	04:54	14:28
21 APR	22h 26m 11s	-11° 19' 42"	Aquarius	+0.9	04:36	14:32
24 MAR	23h 21m 29s	-05° 13' 51"	Aquarius	-2.0	05:45	16:53
31 MAR	23h 27m 37s	-04° 35' 19"	Aquarius	-2.0	06:20	17:36
7 APR	23h 33m 39s	-03° 57' 20"	Aquarius	-2.1	05:55	17:18
14 APR	23h 39m 32s	-03° 20' 08"	Aquarius	-2.1	05:30	17:00
21 APR	23h 45m 17s	-02° 43' 55"	Pisces	-2.1	05:04	16:41
24 MAR	21h 34m 39s	-15° 23' 02"	Capricornus	+0.8	05:00	14:05
31 MAR	21h 37m 18s	-15° 10' 56"	Capricornus	+0.9	05:34	14:42
7 APR	21h 39m 46s	-14° 59' 42"	Capricornus	+0.9	05:08	14:18
14 APR	21h 42m 01s	-14° 49' 30"	Capricornus	+0.9	04:41	13:54
21 APR	21h 44m 03s	-14° 40' 27"	Capricornus	+0.9	04:15	13:29

THIS MONTH'S PLANETS

A planetary parade featuring Jupiter, Venus, Mars and Saturn is something spectacular to look out for in the dawn sky

PLANET OF THE MONTH



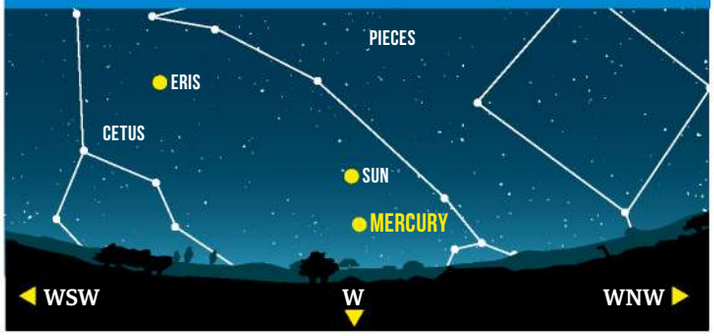
Usually we take a close look at a single planet that's particularly well-placed for observation, or is unusually bright, but this month we're going to look forward to a parade of planets that will be visible in the sky. It's not rare for a couple of planets to appear to meet in the sky. Groupings of more than two planets happen occasionally, but sometimes Earth and the other planets align in such a way that we can see a larger number of them spread out across the sky in a line. This is what will happen in the middle of April. As dawn approaches, Saturn, Mars, Venus and Jupiter will rise one after another in quick succession, forming a chain of worlds spread out from the east to the southeast.

All will be visible to the naked eye, but the sky will already be starting to brighten as Saturn rises. By the time Jupiter rises and they are all above the horizon, sunrise will be only half an hour away, so the full quartet will not be a striking sight. To see this planetary parade, you'll need a very flat and very low eastern horizon; the planets will all be so low in the sky before sunrise that if there are any trees, buildings or hills on your skyline in that direction they will hide the planets from your view, as will any low banks of cloud.

If you can find a suitable observing site – and are blessed with a clear predawn sky – you'll need to be at your chosen location by 04:30 at the latest, ready for the first planet to rise. Take a pair of binoculars with you in case the sky is a little misty or murky to help you spot the planets in the morning twilight.

Saturn will rise first, sliding up from behind the horizon at around 04:30, looking like a yellow-white star. Some 15 minutes or so later, Mars will follow, rising to its lower left and shining with more of an orange hue. Ten minutes or so after that, Venus will join the show, a bright silvery-white 'morning star', but by then the sky will really be starting to brighten as sunrise approaches, and when Jupiter rises around half an hour later it might well be overwhelmed by the morning twilight, but sweeping the sky low down near the horizon should bring it into view.

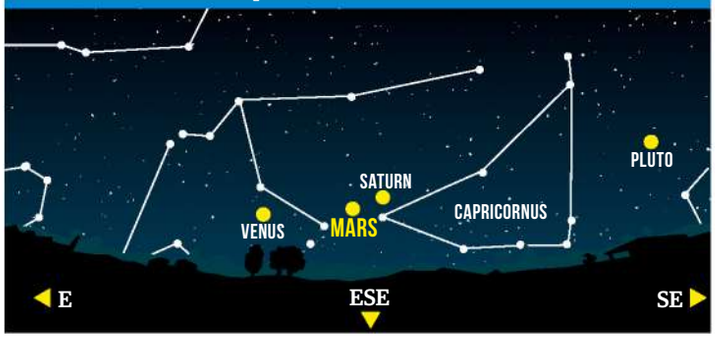
MERCURY 18:30 BST on 29 March



Constellation: Aries **Magnitude:** -1.5 **AM/PM:** PM

At the start of our observing period, Mercury will be too close to the Sun in the sky to be visible, and it will stay that way until early April, when it moves up into the evening sky. By the middle of April Mercury will be a naked-eye 'evening star', shining brightly low in the west-northwest and setting two hours after the Sun.

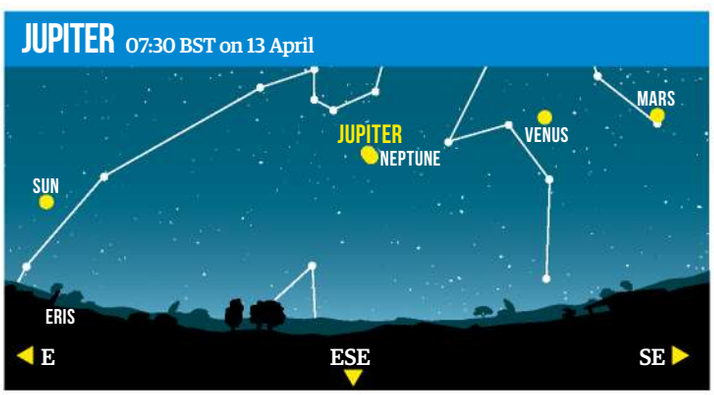
MARS 05:30 BST on 9 April



Constellation: Capricornus **Magnitude:** +1.1 **AM/PM:** AM

During the month ahead, Mars will be a morning object. It should be visible to your naked eye before dawn as an orange-red star, but the brightening sky will reduce its brightness. At the start of our observing period it will be close to Venus, passing just two degrees from it on the morning of 29 March as it takes up its position in the parade of planets.

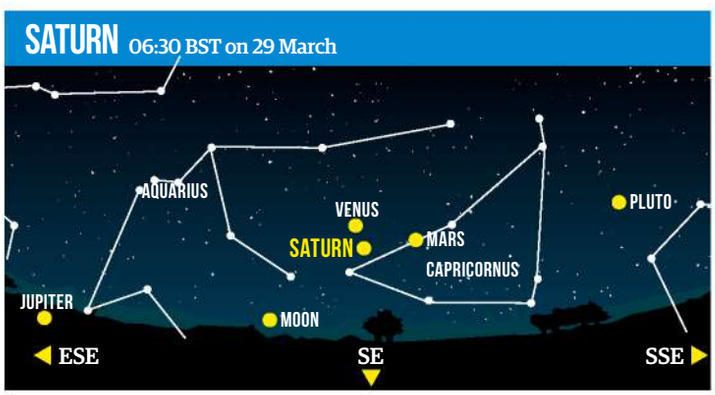
JUPITER 07:30 BST on 13 April



Constellation: Aquarius **Magnitude:** -2.0 **AM/PM:** AM

Despite its impressive magnitude of -2.0, which would make it a strikingly bright naked-eye star in a dark sky, Jupiter will be a challenging morning object during the coming month due to its proximity to the Sun and the bright morning twilight. By the time April rolls around Jupiter will be rising around an hour before the Sun, and will be part of the parade of planets.

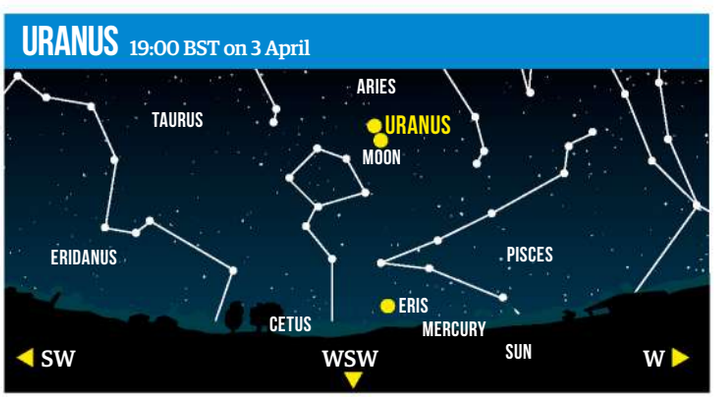
SATURN 06:30 BST on 29 March



Constellation: Capricornus **Magnitude:** +0.9 **AM/PM:** AM

Saturn will be a morning object during the month ahead, and will be at the head of the parade of planets. As with all the other planets involved, Saturn's brightness in the sky will be affected both by its low altitude and the brightness of the predawn sky itself, so if you're determined to see it, have a pair of binoculars handy to help you.

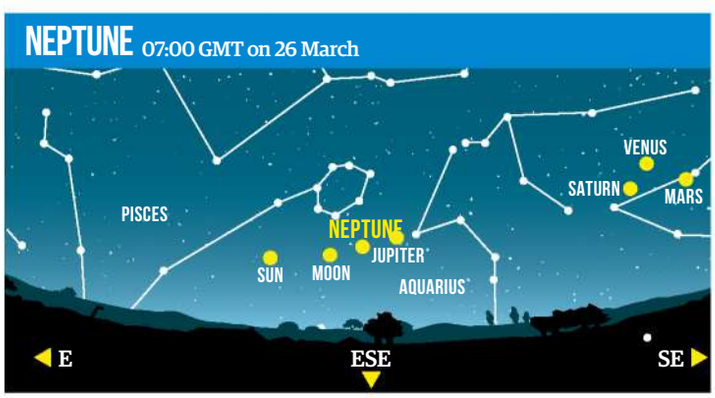
URANUS 19:00 BST on 3 April



Constellation: Aries **Magnitude:** +5.8 **AM/PM:** PM

Uranus is visible in the evening sky as a green-hued star, and at magnitude +5.8 will technically be a naked-eye object, but you'll need binoculars and a chart to identify it accurately. By the end of our observing period Uranus will be setting just 90 minutes after the Sun, and will appear close to much brighter Mercury in the evening twilight.

NEPTUNE 07:00 GMT on 26 March



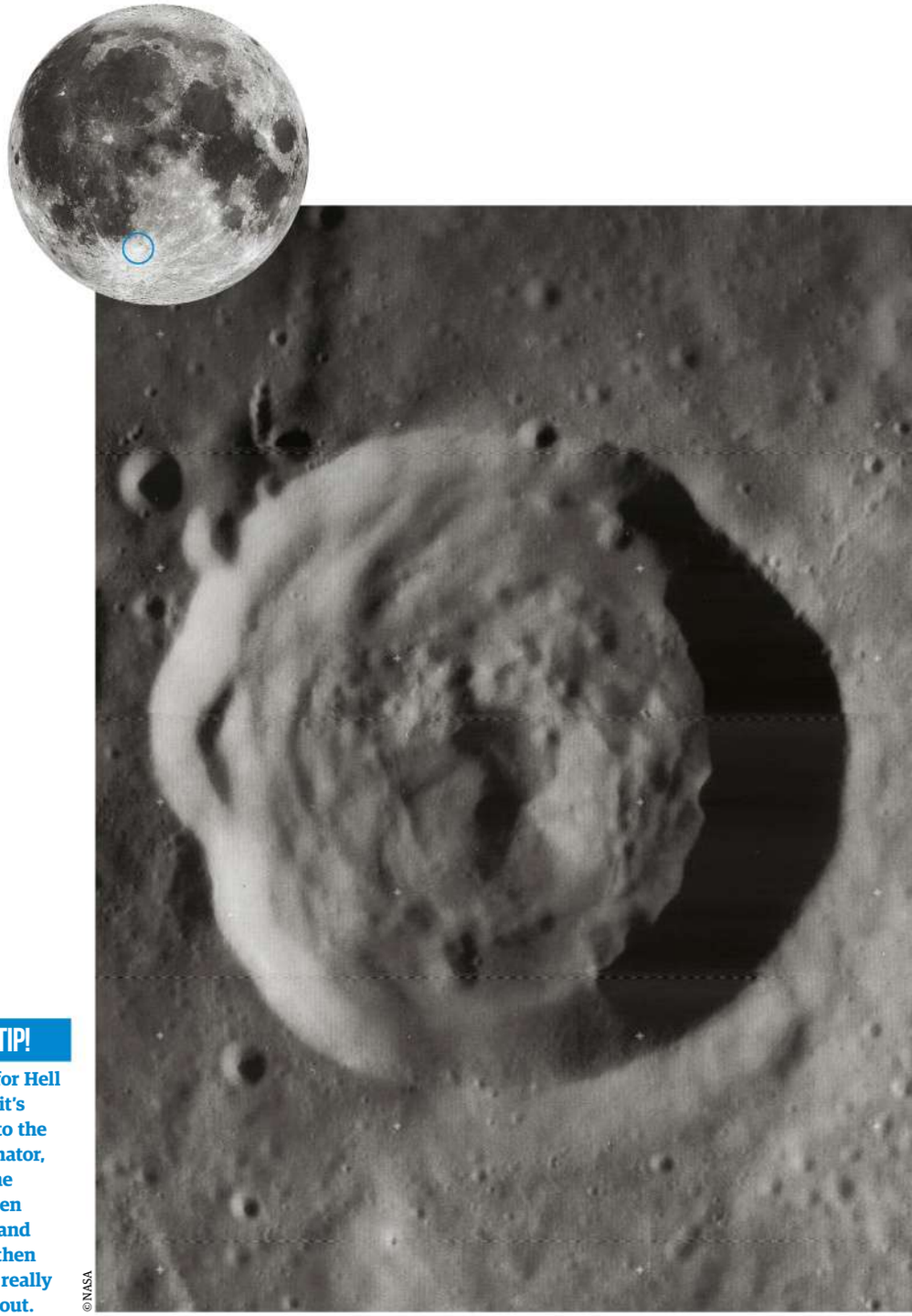
Constellation: Aquarius **Magnitude:** +8.0 **AM/PM:** AM

At the start of our observing period Neptune will be too close to the Sun to be visible. When it moves away from the Sun it will form part of the planetary parade, but will be too faint to see. Seeing Neptune requires a pair of binoculars or a telescope, but you'll have almost no chance of seeing it this month, as it will be very low in the brightening eastern sky.

MOON TOUR

HELL

Finding this fascinating crater isn't as hard as its name suggests



©NASA

TOP TIP!

Look for Hell when it's close to the terminator, the line between night and day – then it will really stand out.

The lunar landscape down towards and around its south pole is wild, craggy and rugged; a raw, bare-rock wilderness of walled plains, huge craters and towering mountains all blasted out by a brutal asteroid bombardment many millennia ago. In the southern lunar highlands there are too many craters to count, as they overlap and overlay each other. The most ancient craters have smaller, younger craters inside them, and many of those smaller craters have even smaller, even younger craters inside them. Exploring this cluttered landscape through a telescope is both thrilling and bewildering – there's so much to see! Naturally, the huge impact craters of Clavius, Maginus and Tycho draw the eye, but a little further to their north and east lies a much smaller crater with a short but intriguing name that few people know about, and even fewer have ever taken a good look at while touring the huge features around it.

Compared to the giant wounds around it, Hell is a small impact crater. With a diameter of 33 kilometres (20.5 miles) it's just a third as wide as nearby Tycho, and its depth of 2.2 kilometres (1.4 miles) makes it half as deep as that better known crater. But this small crater, which lies in the western half of the sprawling Deslandres walled plain, offers a lot to the lunar observer willing to drag their gaze away from the 'celebrity features' around it.

Roughly circular, Hell's rim is sharp, but otherwise quite unremarkable. The crater's main appeal is the complicated nature of its floor: it's covered with countless lumps and bumps which really stand out when the crater is near the terminator and the Sun is hitting the crater floor at a low angle. At high magnification Hell's floor is a fascinating sight, and the features on its floor form a subtle spiral shape.

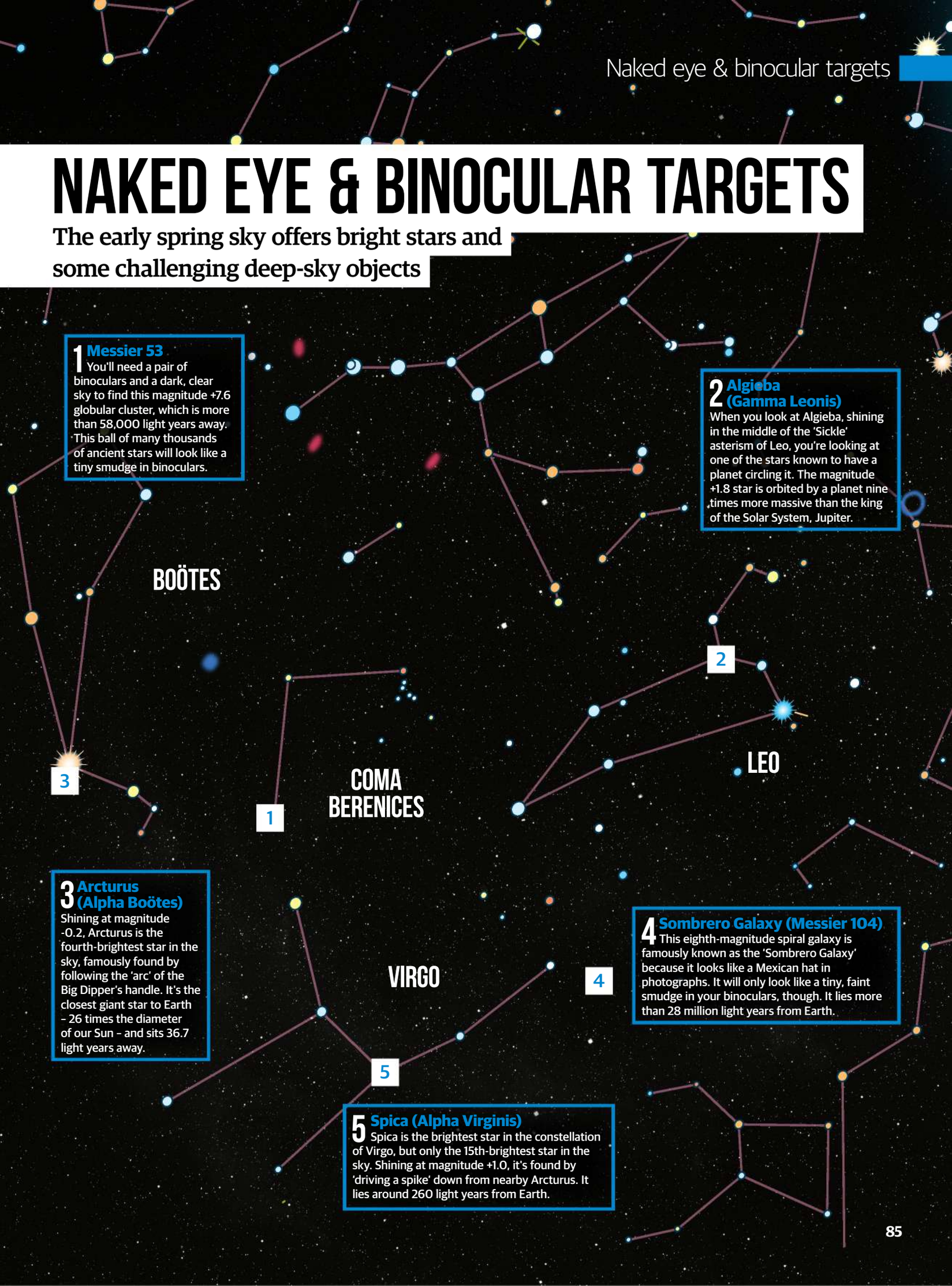
When Hell was formed millions of years ago, a huge amount of debris was thrown up by the impact – debris which rained down on the landscape around it in a blizzard of boulders, rocks and stones. This hail of wreckage blasted 19 smaller 'satellite' craters out of the surface around Hell, and it's fun to tour these through your telescope using a high-magnification eyepiece.

So when can you see this crater for yourself this month? At the start of our observing period Hell is just ahead of the terminator, and hard to see, but a medium or large telescope should still be able to pick it out from the surface as a dark pit. By 27 March the crater will have vanished from view, swallowed up by the inky blackness of lunar night. Hell will reappear as the Moon becomes sufficiently illuminated on the evening of 11 April. As the terminator sweeps over it and the Sun's low, slanting rays shine down into it, Hell will be a striking sight through a telescope, looking like a skull's empty eye socket. Over the next few evenings the crater will become more and more illuminated but less obvious, and by full Moon on 16 April will resemble a light ring with a dark interior. But unlike many lunar craters, Hell won't vanish at full Moon; it will still be quite easy to see. On 25 April the terminator will sweep back over the crater, stealing it from our view.

But what about that intriguing name? Why is a crater on the silent, dusty, dead Moon named after a place where the souls of the damned writhe in a sea of fire and flame? Actually, it isn't. Hell was named in honour of a Hungarian astronomer and Jesuit priest, Maximilian Hell. In 1756 Hell became the director of the Vienna Observatory, and 13 years later travelled to the far north of Norway to observe the 1769 transit of Venus. And is there a 'Heaven' crater on the Moon, for the sake of balance? Sadly not, nor on any other planet in the Solar System. But surely, on some day in the future, a crater on a world orbiting another star, out there in the depths of space, will be.

NAKED EYE & BINOCULAR TARGETS

The early spring sky offers bright stars and some challenging deep-sky objects



1 Messier 53
You'll need a pair of binoculars and a dark, clear sky to find this magnitude +7.6 globular cluster, which is more than 58,000 light years away. This ball of many thousands of ancient stars will look like a tiny smudge in binoculars.

2 Algieba (Gamma Leonis)
When you look at Algieba, shining in the middle of the 'Sickle' asterism of Leo, you're looking at one of the stars known to have a planet circling it. The magnitude +1.8 star is orbited by a planet nine times more massive than the king of the Solar System, Jupiter.

3 Arcturus (Alpha Boötes)
Shining at magnitude -0.2, Arcturus is the fourth-brightest star in the sky, famously found by following the 'arc' of the Big Dipper's handle. It's the closest giant star to Earth – 26 times the diameter of our Sun – and sits 36.7 light years away.

4 Sombrero Galaxy (Messier 104)
This eighth-magnitude spiral galaxy is famously known as the 'Sombrero Galaxy' because it looks like a Mexican hat in photographs. It will only look like a tiny, faint smudge in your binoculars, though. It lies more than 28 million light years from Earth.

5 Spica (Alpha Virginis)
Spica is the brightest star in the constellation of Virgo, but only the 15th-brightest star in the sky. Shining at magnitude +1.0, it's found by 'driving a spike' down from nearby Arcturus. It lies around 260 light years from Earth.

Messier 106

DEEP SKY CHALLENGE

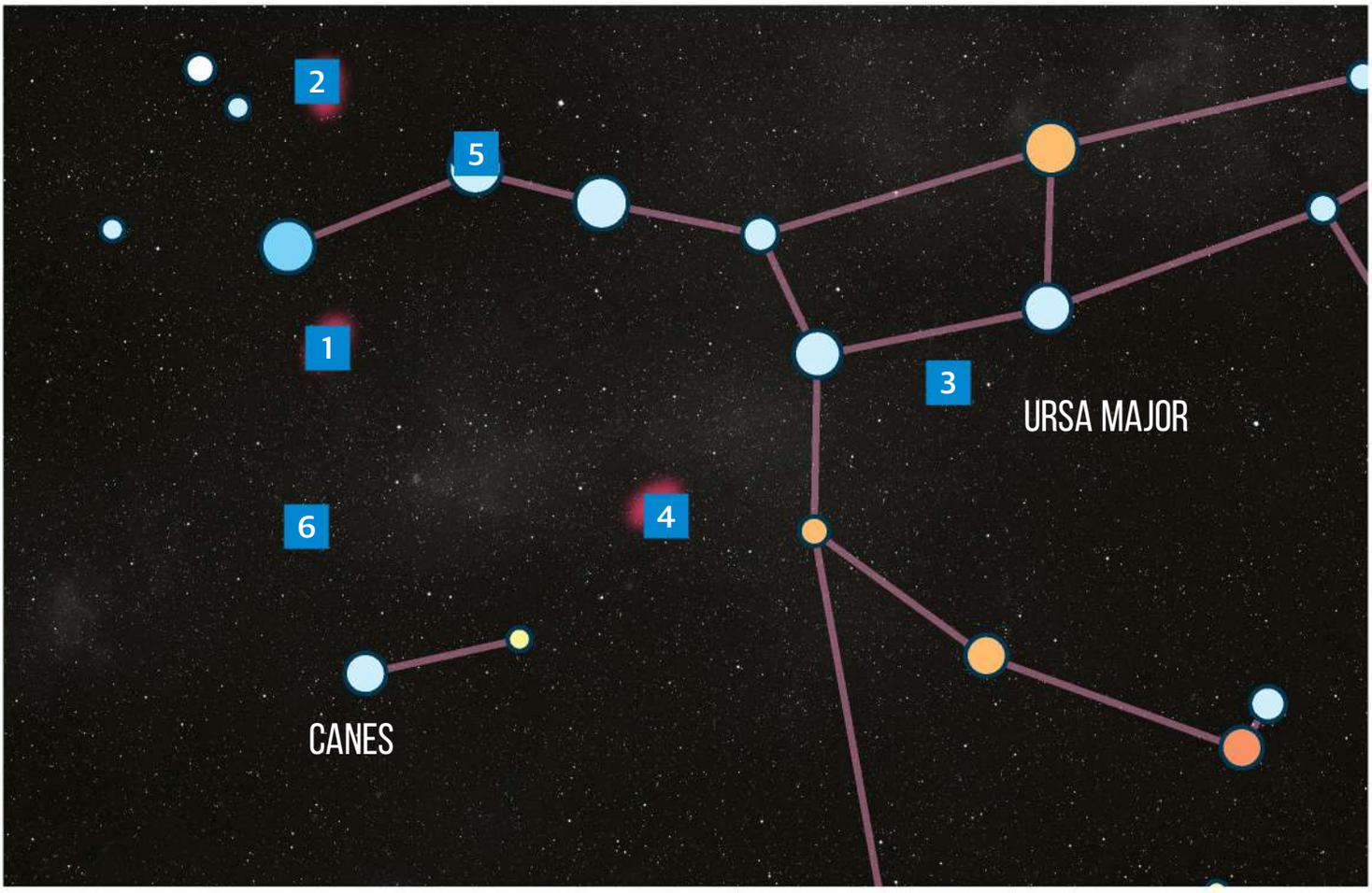
NIGHT-SKY JEWELS OF THE HUNTING DOGS AND THE GREAT BEAR

Spring has arrived, and with it a wealth of deep-sky objects on which to turn your telescope

For those of us in the Northern Hemisphere, high overhead on spring nights can be found the constellations of Canes Venatici (the Hunting Dogs) and Ursa Major (the Great Bear). Both contain several bright, distant galaxies, along with many fainter ones and interesting nebulae. Possibly the most famous of all the double stars, which is in fact a multiple star system, lies in this region, too. There are some well-known galaxies that will be relatively easy targets for even small telescopes, but many will require a larger aperture and dark skies to see well.

Sunflower Galaxy (Messier 63)

x2 Images © NASA, ESA, the Hubble Heritage Team



"BOTH CONTAIN SEVERAL BRIGHT, DISTANT GALAXIES, ALONG WITH MANY FAINTER ONES AND INTERESTING NEBULAE"

1 The Whirlpool Galaxy (Messier 51)
Use the tip of the Great Bear's tail to find this interacting galaxy. You'll need at least a small telescope to pick out a diffuse patch of light with a bright central region at its heart.

2 Pinwheel Galaxy (Messier 101)
Telescopes with an aperture of about three inches will reveal a nebulous haze with a bright centre, while an eight-inch instrument will show a bright, condensed core surrounded by nebulosity.

3 The Owl Nebula (Messier 97)
This is a planetary nebula – a star which has shed its outer shell of gas. Larger telescopes will show two dark patches that give this deep-sky object its appearance.

4 Messier 106
Spiral galaxy Messier 106 can be picked up using binoculars, while small telescopes show a diffuse patch with a bright centre. An eight-inch instrument will reveal details of the galaxy's structure.

5 Mizar and Alcor
The widest of the naked-eye double stars. Through a field of view, the stellar duo twinkle as a pair of white-blue jewels. Alcor is the faintest of the pairing with a magnitude of +4.0.

6 Sunflower Galaxy (Messier 63)
One of the prettiest spiral galaxies in the night sky. A large telescope with medium power shows it well. With the right aperture – usually ten inches or more – you can pick out the dust lanes.

Messier 101

© NASA/ESA

THE NORTHERN HEMISPHERE

Spring lets you look out of the plane of the Milky Way, while some bright stars of winter still linger

Bright yellow-white star Capella of Auriga (the Charioteer) sits low in the northwestern sky this month, a striking sight at magnitude +0.08, alongside easy-to-find Castor and Pollux of Gemini (the Twins). Ursa Major's 'Big Dipper' is the easiest asterism to find as soon as darkness falls, making it easy to use its pointer stars to find Polaris. Follow the pointers in the other direction and you'll find bright-white star Regulus in Leo (the Lion), and trace your finger along the bowl and you'll find yourself led to brilliant yellow-orange star Arcturus in the constellation of Boötes (the Herdsman). Nearby, just northeast of Arcturus, you'll be greeted by the unmistakable semicircle of the Northern Crown, Corona Borealis.

USING THE SKY CHART

This chart is for use at 22:00 mid-month and is set for 52° latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

MAGNITUDES

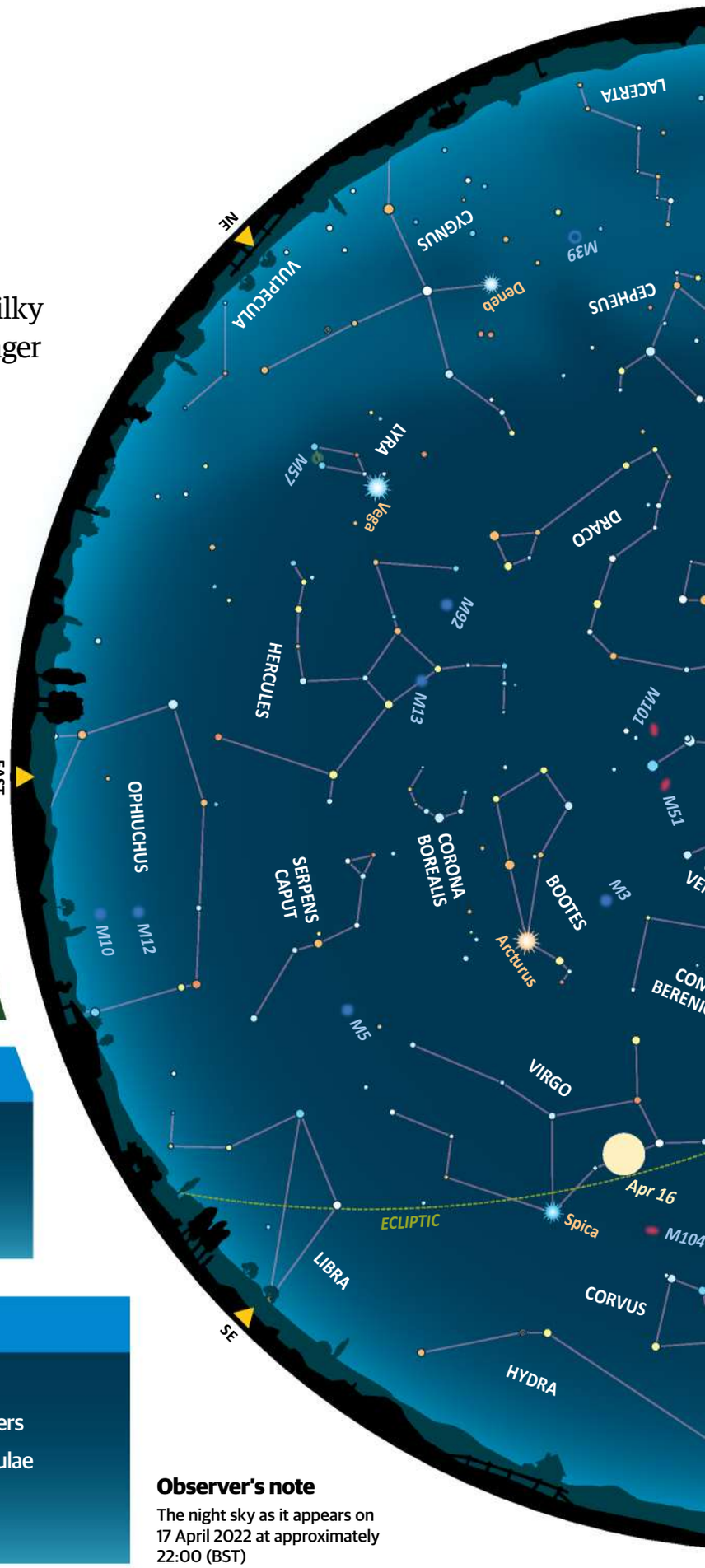
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

SPECTRAL TYPES

- O-B
- A
- F
- G
- K
- M

DEEP-SKY OBJECTS

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

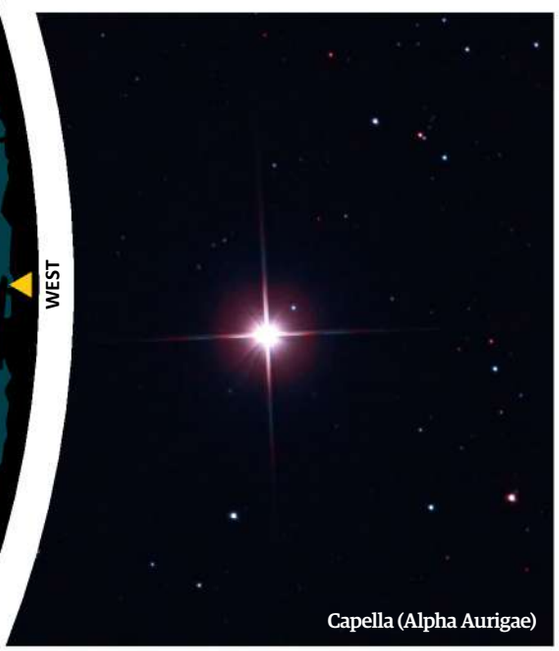


Observer's note

The night sky as it appears on 17 April 2022 at approximately 22:00 (BST)

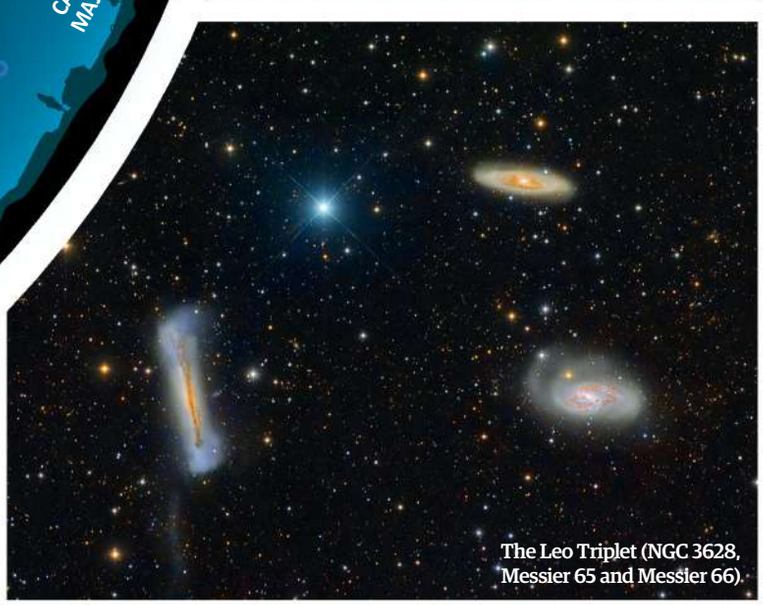
Cat's Eye Nebula (NGC 6543)

© NASA/ESA



Capella (Alpha Aurigae)

© Getty



The Leo Triplet (NGC 3628, Messier 65 and Messier 66)

© Getty

ASTROSHOTS OF THE MONTH

Get featured in **All About Space** by sending your astrophotography images to **space@spaceanswers.com**

Soumyadeep Mukherjee

Location: West Bengal, India, and El Sauce Observatory, Chile

Telescope: FSQ-106ED and Telescope Live

"I'm an amateur photographer from India and have been imaging objects in the sky for the last 1.5 years. My first image shows the location near the bright star Rigel; IC 2118 is an extremely faint reflection nebula spanning almost 70 light years across. It's popularly known as the Witch Head Nebula. My second image frames the heart of Carina Nebula, a gem of the Southern Hemisphere sky."

Above: Carina Nebula

Right: Witch Head Nebula

Left: Horsehead Nebula

Jaspal Chadha

Location: London, UK

Telescope: Takahashi 130

"I have been imaging for around two-and-a-half years now after spending years looking through various telescopes and eyepieces, where I enjoyed learning all about the objects in the night sky. After months of research and trial and error, I finally invested in a set-up that I thought would work for me. My biggest challenge has been to fend off the myths around imaging in light-polluted areas, as I live in London. I started out with DSLR astrophotography but now use a CCD to capture a wide range of night-sky targets."

Basudeb Chakrabarti

Location: IC Astronomy, Oria, Spain

Telescope: Officina Stellare 700 RC and Telescope Live

"We are a group of five like-minded people who always discuss, share and learn different aspects of astronomy and astrophotography. The night sky always fascinated us. In 2020, we got some time to nurture the interest of astronomy using some basic telescopes, and gradually upgraded to some basic astrogears. As we reside in the Bortle 9 and highly air-polluted zone of Kolkata, it's quite difficult to do astrophotography from our place with our basic set-ups, so we try to travel to nearby Bortle zones for imaging, managing our professional commitments. It's really a pleasure to see the end results after long sessions and hours of post-processing.

Above: The Pleiades (Messier 45)

Left: Cosmic Flying Bat and Giant Squid

Right: Whirlpool Galaxy (Messier 51)

CANON 10x42L IS WP BINOCULAR

An outstanding choice for super-steady stargazing thanks to fabulous image stabilisation, a waterproof design and large objective lenses

Reviewed by Jamie Carter

ADVICE

Cost: £1,699.99 / $1,499

From: Canon

Magnification: 10x

Objective lens diameter: 42mm

Angular field of view: 6.5 degrees

Eye relief: 1.4 centimetres (0.57 inches)

Weight: 1.1 kilograms

BEST FOR...

£ LARGE BUDGETS

! INTERMEDIATE

STARS & CONSTELLATIONS

PLANETS

MOON PHASES

BRIGHT DEEP-SKY

The only member of Canon's L Series of binoculars, not only do they come equipped with astronomy-centric glass, but also boast Canon's Image Stabilisation (IS). Though not exclusive to Canon, the IS system is not widely used. That's partly because it's so expensive, though few who have had the good fortune to try this electronic system consisting of motion sensors and a vari-angle prism will say it's not worth the outlay. It works like a dream; you press a button and the 'shake' disappears. For anyone who's struggled with keeping binoculars steady enough for properly immersive stargazing, the Canon 10x42L IS WP is the answer. Not only does it come at a price, but there are a few drawbacks. The IS system takes significant battery power and the package includes some disappointing lens caps. However, as a technologically advanced binocular for astronomy, the 10x42L IS WP is hard to beat.

The 10x42L IS WP is designed to withstand more than the clear skies amateur astronomers play under. In fact, the waterproof design makes it as suited to extreme weather conditions as to astronomy. Either way, the size and weight make it sturdy to the point of being too heavy to hold steady. Cue Canon's IS technology, a system of electronics that effortlessly takes the shakes out of stargazing. In keeping with many advanced astronomy-centric binoculars, the 10x42L IS WP boasts a Porro prism design, though it's the vari-angle abilities that are particularly advanced. It uses a system of gyroscope motion sensors to detect how much your arms are moving and how much wobble they're introducing to the image you see. Some actuators around the lenses then cancel out that wobble to a correction angle of 0.8 degrees. What happens is that the vari-angle prism moves to correct the refraction angle of incoming light. It works in an instant; you just touch the push button on top of the right-hand side's barrel.

However, the optical quality goes way beyond electronics. The 10x42L IS WP features ultra-low dispersion lens elements which make single points of light clearer – an obvious advantage when stargazing – and give accurate colours. The objective lenses have Canon's multi-layered anti-reflective lens coating, 'Super Spectra', to avoid ghosting, lens flare and improve colour reproduction. We also think the 6.5-degree field of view makes the 10x42L IS WP ideal for general astronomy; anything with more magnification is verging on deep-sky astronomy. The Canon 10x42L IS WP is designed to not need a tripod, but just in case you want to easily share observations with others it does include a standard tripod thread on the undercarriage.

Where the Canon 10x42L IS WP as a package generally disappoints is with the extra gear in the box. The exception is a neck strap, which uses neoprene and is comfortable, adjustable yet fairly short. The eyepieces have a joint cover that protects both simultaneously, though it's fairly loose. Thankfully it's got a loop that can be attached to the neck strap so it doesn't get lost. What we found most disappointing was the lens cap for the objective lenses. Provided as a one piece and also with a loop to attach to the strap, this slim rubber cap does a poor job of staying in place. The 10x42L IS WP's saving grace is that it has a 52mm filter thread so can easily and cheaply

© Canon

Left: Though sturdy, the binocular is quite heavy

be upgraded to Canon LC-52 Centre Pinch lens caps, widely available for Canon's camera lenses. You might also want to think about upgrading the carrying case, which is very basic and flimsy. At this high price, these oversights are a shame.

Though aimed as much at maritime users and birdwatchers, the Canon 10x42L IS WP really comes into its own for stargazing. With an exit pupil diameter of 4.2mm and those 42mm objective lenses, it performs excellently in low light, providing a bright high-resolution view all night long. During the day it also offers close focus of 2.5 metres (8.2 feet), which is useful when birdwatching, though it can be slightly slow to focus. That's partly down to the ponderous focusing ring that's set on the bridge of this binocular. When used in collaboration with the usual diopter ring around the right-hand eyepiece, the Canon 10x42L IS WP proved easy to calibrate.

"THE CANON 10X42L IS WP REALLY COMES INTO ITS OWN FOR STARGAZING"

The IS system is so good it's addictive, though it does have its limits. Its actuators can cancel out shake to an angle of 0.8 degrees, so if you're wildly moving the Canon 10x42L IS WP then the stars will still wobble incessantly. Although it's capable of unrivalled detail and clarity, a slight drawback can be that even when you're as still as possible and IS is engaged there sometimes exists a tiny amount of softness in the stabilised image. It's most easily kept to a minimum by pretending that the Canon 10x42L IS WP doesn't have that 'magical' IS mode at all. The usual techniques – bringing your elbows into your core, leaning against a wall or sitting or lying down – while using binoculars should still be employed to ensure the Canon 10x42L IS WP is correcting as little as possible. The result of doing that is incredible sharpness. You'll be gazing up at the Moon for hours – same for the Pleiades and other star clusters, the Orion Nebula and everything else in the night sky. The UD lens elements and Super Spectra lens coatings keep images bright, while the 'L' glass means low dispersion, so no chromatic aberration on brighter objects.

The wondrous effect of the IS system is that you're going to want to use the Canon 10x42L IS WP for longer than you would most astronomy binoculars for the very reason that you get an addictive super-steady view. At over a kilogram that's not always easy in practice, because your neck will start to ache, though something else that does make the 10x42L IS WP comfortable to use for long periods is its generous eye relief. The binocular has pull-out eyecups that gently twist out to 16mm. As well as making the 10x42L IS WP suitable for anyone who wears glasses, those twist-out eyecups also help block out ambient light sources and encourage a more immersive view.

But there's a drawback. After you depress the IS button, that mode kicks in and a red LED lights up, but it disengages after about a minute to save power. That's useful because the IS circuitry uses a lot of battery power. Canon quotes 2.5 hours at temperatures over 25 degrees Celsius (77 degrees Fahrenheit) and just ten minutes at -10 degrees Celsius (14 degrees Fahrenheit). In cold conditions, it's more like the latter, meaning you have to use the IS sparingly, but you also need to carry with you a spare pack of AAA batteries – or two.

The Canon 10x42L IS WP isn't perfect, but it's as close as you'll get for handheld astronomy. The binocular eats up AAA batteries in cold weather, the included accessories are generally poor – save for the excellent neck strap – and they are incredibly expensive. But the reason for the latter is the Canon 10x42L IS WP's advanced optics and the addictive electronic wizardry that is IS circuitry. Correcting for the wobble and judder that comes for the Canon 10x42L IS WP being handheld and therefore ridding images of wiggly stars, it's the perfect solution for anyone who wants a long, lingering look at the Moon, stars, open clusters and bright nebulae. Easy to travel with and as outdoorsy a binocular as you'll find, the weatherproof and wonderful Canon 10x42L IS WP is capable of revolutionising how you do astronomy. Who needs a telescope?

© Canon

Above: The neck strap is the perfect accessory

FOR

- Optical Image Stabiliser
- Excellent quality optics
- Rugged outdoorsy design
- Generous eye relief
- Built-in tripod thread

AGAINST

- Heavy
- It requires a lot of AAA batteries
- Loose lens caps
- Very expensive

Future Genius

THE BRAND NEW

EDUTAINMENT BOOKS FOR KIDS!

For ages 7+

OUT NOW!

WATCH VIDEOS WITH OUR INCREDIBLE INTERACTIVE EXPERIENCE

on SALE now

★ Solar System ★ Cool Chemistry
★ Human Body ★ Animal Kingdom
★ Ancient Egyptians
★ Computers & Learn to Code ★ Weather

GET YOURS NOW FROM MAGAZINESDIRECT.COM
AND ALL GOOD SUPERMARKETS AND NEWSAGENTS

✚ Puzzles ✚ Activities ✚ Experiments ✚ Facts ✚ More!

SPACE HISTORY COLLECTION

FREE FOR EVERY READER

NEW
HEROES OF SPACE
THE SCIENTISTS & EXPLORERS WHO CHANGED THE UNI
Digital Edition
HEROIC CREWS • DARING LAUNCHES • INCREDIBLE
NEW
HISTORY OF NASA
THE FASCINATING STORY OF THE ICONIC AMERICAN SPACE AGENCY
CELEBRATE OVER 60 YEARS OF EXPLORING SPACE
Digital Edition
The SPACE RACE
COSMIC BATTLE FOR THE STARS
SPUTNIK • APOLLO MISSIONS • CREATING NASA • MAN ON THE MOON
WORTH £30

HEROES OF SPACE

The history of space is a heroic one – it takes courage to climb aboard a rocket and head out beyond the atmosphere, especially if you're one of the first pioneers to do so. But space exploration has other heroes apart from the brave astronauts and cosmonauts who were first to leave Earth. They wouldn't have been able to do so without the pioneering work of generations of scientists who tackled the complex theories of astrophysics and the logistics of space travel, often persisting in the face of condemnation and censure. Here you'll meet some of the people who have made space exploration possible. Some are easy to define as heroes: they took on exceptional challenges, and some of them made the ultimate sacrifice, while others have more complex legacies.

HISTORY OF NASA

On 29 July 1958, President Dwight D. Eisenhower signed into US law a federal statute that would change the universe forever. The terms of the National Aeronautics and Space Act set out objectives for the creation of a civilian space agency in America, one that was not controlled by generals, intelligence officials or businessmen, but by scientists. An agency whose aim was not war, but peace. NASA was born.

In the almost 64 years since its inception, NASA has been responsible for some of the most important advances humankind has ever made. No other organisation has ever gone beyond the boundaries of nationality and politics to embody humanity's curiosity, vision and ambition in the way that NASA has. It has shown us what it is possible to achieve.

BOOK OF THE SPACE RACE

The Soviet Union surprised the world and kicked off the Space Race by launching Sputnik, the satellite that became the first human-made object to orbit Earth. The US had to respond – and in a big way. Over the next decade, the two countries battled it out to gain important victories over one another, culminating in NASA's Apollo 11 mission in 1969. But the Space Race didn't end there – the 1970s ushered in an era of new achievements, and even cooperation between the former rivals. Flick through the pages of this book to find out more about the golden era of space exploration, get to know the astronauts and their teams, revel in the joy of a good mission and see what went wrong in tragic disasters. Finally, look into the future to see where humans may put their footprint next.

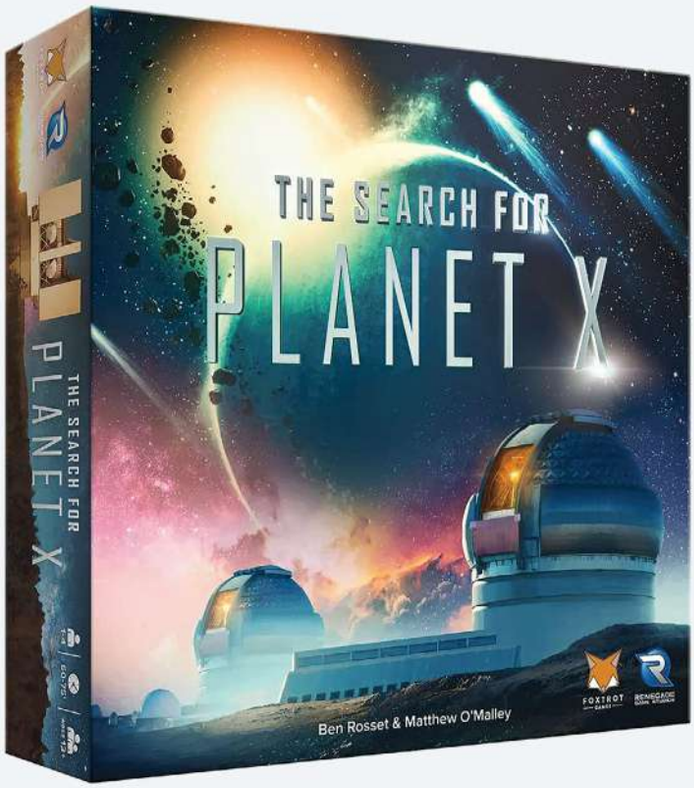
DOWNLOAD YOURS NOW AT: SURVEYMONKEY.CO.UK/R/AAS_EBOOKS_128

IN THE SHOPS

The latest books, apps, software, tech and accessories for space and astronomy fans alike

1

2



3

FOR HOT OR COLD DRINKS

ROOT7 X SCIENCE MUSEUM NEBULA WATER BOTTLE

Cost: £25 (approx. $32.75)

From: shop.sciencemuseum.org.uk

1 Cut down on your single plastic use and experience the wonders of the universe at the same time with this high-quality Root7 x Science Museum Nebula Water Bottle. The stainless-steel bottle is double-walled and has an interior copper lining for added insulation. This clever design means that your cold drinks can be kept cold for up to 30 hours or hot drinks hot for 20 hours. The bottle features a stunning image of the Carina Nebula captured by the Hubble Space Telescope.

FOR FUN

THE SEARCH FOR PLANET X

Cost: £41.38 / $44.99

From: amazon.co.uk / amazon.com

2 Do you think you could be the first to discover the location of Planet X? Embark on a challenge of deduction with up to three other players and use the board game's free companion app to randomly select an arrangement of objects and a location for Planet X. Perform scans of the universe and attend scientific conferences to try and find clues as to the whereabouts of Planet X. The winner is the first player to successfully guess the location of the elusive planet. The game is designed for one to four players, ages 13 and up.

FOR OBSERVING

OPTICRON MONOCULAR BGA 8x42

Cost: £149 (approx. $195.25)

From: opticron.co.uk

3 The 8x magnification and 42mm objectives make it an excellent choice for stargazers, backpackers, travellers and hikers looking for something to use on the go. Easy for glasses-wearers to use, the Opticron BGA 8x42 is waterproof to three metres (9.8 feet) is nitrogen-filled, so fog-proof, and comes with a handy leather carry case and a neoprene carrying strap. Thanks to the Opticron S-type multi-coating on the optical system, it boasts plenty of contrast, clarity and a definite high-end feel.

"GUARANTEED TO MAKE A STATEMENT DURING YOUR NEXT WORKOUT, THE MAT IS BOTH SOFT AND SUPPORTIVE"

FOR EXERCISE

YOGI BARE COSMIC PRINT GYM MAT

Cost: £49 / $66

From: thesportsedit.com

4 Take your workouts to a whole new level with this cosmic-print yoga mat by eco-conscious fitness brand Yogi Bare. Guaranteed to make a statement during your next workout, the mat is both soft and supportive, with non-slip features. The whimsical stellar-print mat is made from natural rubber, complete with fibre towelling technology, and is machine washable. The lightweight mat measures 183 by 61 centimetres (73 by 24 inches) and is 2 millimetres thick.

FOR YOUR HOME OR OFFICE

EUROPEAN SPACE AGENCY #GIVEMESPACE MUG

Cost: £13.40 / $17.58

From: esaspaceshop.com

5 We all need a little bit of space from time to time. With many of us returning to offices after a long stint working from home, we may feel the need to communicate it more clearly with certain colleagues. Why not say it with a mug? Practical in more ways than one, this ceramic ESA mug holds 330 millilitres and stands 9.5 centimetres (3.7 inches) tall and 8.2 centimetres (3.2 inches) wide. The ESA's #GiveMeSpace collection is available for a limited time only.

FOR YOUR HOME

CONSTELLATION COASTERS

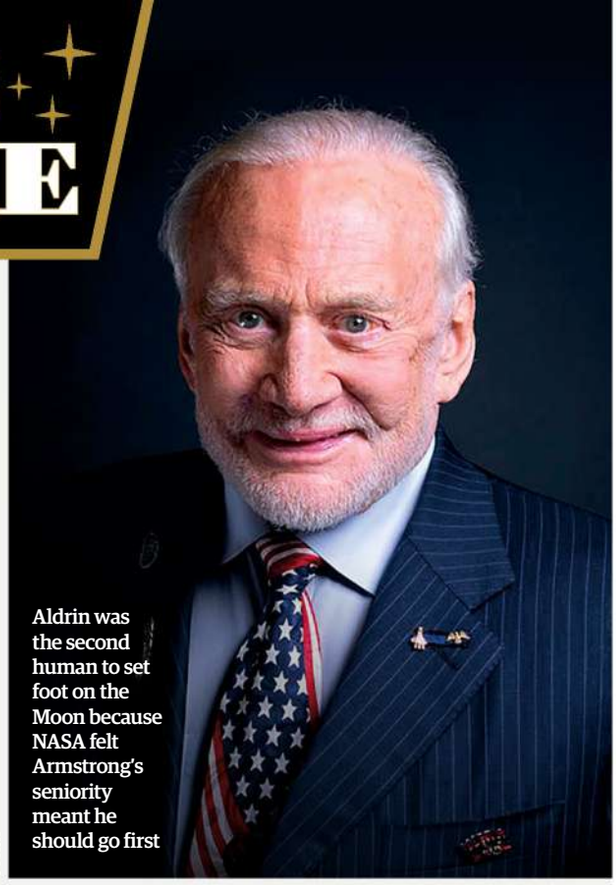
Cost: £34 (approx. $44.55)

From: westelm.co.uk

6 Elevate your living space with this set of four celestial coasters inspired by the night sky. The glass coasters are adorned with delicate starry details against a rich blue backdrop. Each coaster measures ten centimetres (3.9 inches) in diameter and is 0.5 centimetres (0.2 inches) thick, and the rubber-dot backing ensures they stay put and protect your furniture. It's recommended that you clean the coasters with a soft, damp cloth.

EDWIN EUGENE "BUZZ" ALDRIN

Serving as the Lunar Module pilot, the US astronaut was the second person on the Moon



Aldrin was the second human to set foot on the Moon because NASA felt Armstrong's seniority meant he should go first

© NASA

Aldrin was born on 20 January 1930 in Glen Ridge, New Jersey. During his childhood he didn't display any great interest in space. He was intrigued by science fiction – Buck Rogers and Flash Gordon in particular – but he didn't look towards the night sky with a great desire to explore. Growing up in Montclair, New Jersey, Aldrin was a bright and athletic child. He graduated from Montclair High School a year early, and in 1947 he enrolled at the United States Military Academy, also known as West Point, where he gained a bachelor of science in mechanical engineering. Joining the United States Air Force, he served with distinction as a jet fighter pilot during the Korean War, which raged between 1950 and 1953.

Deciding to go back to university in 1959, he earned a doctor of science in astronautics at the Massachusetts Institute of Technology. Shortly after graduating four years later, he was selected by NASA to become an astronaut. It was the second time he had applied, having been inspired by his friend Ed White's acceptance onto the Gemini program.

In 1961, after Yuri Gagarin's spacefaring achievement, US president John F. Kennedy announced his intention to land a man on the Moon and return him safely to Earth. To aid such a mission, Aldrin built on the knowledge gained during his thesis and worked on docking and rendezvous techniques for spacecraft in Earth and lunar orbit. Becoming known as 'Dr Rendezvous', Aldrin also pioneered underwater training techniques to simulate spacewalking, which would prepare astronauts to work in a weightless environment.

NASA also set up the Apollo space program. It was a three-person spacecraft as opposed to the two-person Gemini project, and its primary aim was to land astronauts on the Moon. Aldrin became part of the backup crew for Apollo 8, having been assigned as the Command Module pilot, and he worked with commander Neil Armstrong and Lunar Module pilot Fred W. Haise Jr. Although it didn't see him venture into space, Aldrin's time would come with Apollo 11, which launched from Cape Kennedy on 16 July 1969. He was the Lunar Module pilot, Armstrong was commander and Michael Collins was the Command Module pilot.

The mission made history, touching down with just 30 seconds of fuel left in the landing tank and overshooting the intended location by four miles. Armstrong set foot on the Moon first, followed by Aldrin 19 minutes later. The event was watched by an estimated 650 million people on television, and Aldrin would describe the Moon as "magnificent desolation".

Aldrin, Armstrong and Collins' work was more important than simply allowing NASA to get one over on their Soviet counterparts. Aldrin and Armstrong spent 21 hours and 36 minutes on the lunar surface, using that time to collect samples as well as take photographs and videos. They also conducted experiments, took a phone call from President Richard Nixon and planted the American flag. As an elder at Webster Presbyterian Church, Aldrin performed a Christian communion on the Moon, having taken bread and wine with him.

He and Armstrong almost didn't make it back from the surface, however. A circuit breaker switch broke off the instrument panel and they had to find a way of pushing it back in so that the ascent engine could ignite. Aldrin decided to use a felt-tipped pen, and it worked. When the astronauts finally got back to Earth, they were treated as heroes and embarked on a world tour. But although Aldrin was awarded the Presidential Medal of Freedom and helped design the Space Shuttle, he didn't enjoy being in the limelight. He retired from NASA in 1971 to return to the Air Force. He then retired from active duty the following year.

All About Space

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Content Director **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Production Editor **Nikole Robinson**
Senior Art Editor **Duncan Crook**
Photography **Olly Curtis**

Contributors
Stuart Atkinson, Toby Brown, Jamie Carter, Charles Q. Choi, David Crookes, Daisy Dobrijevic, Andrea Font, Brad Gibson, Chelsea Gohd, Robin Hague, Ailsa Harvey, Elizabeth Howell, Chris James, Maggie Lieu, Samantha Mathewson, Robert Pearlman, David Perley, Tereza Pultarova, Nikole Robinson, Mark Sephton, Giles Sparrow, Ben Turner

Cover images
Tobias Roetsch ; Getty

Photography
Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons;
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Advertising Manager **Matthew Johnson**
matthew.johnston@futurenet.com
07974 408 083
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
0330 390 6637

International Licensing and Syndication
All About Space is available for licensing and syndication. To find out more contact us at **licensing@futurenet.com** or view our available content at **www.futurecontenthub.com**.
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas orderline & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
Group Marketing Director, Magazines & Memberships **Sharon Todd**
Disruption remains within UK and international delivery networks. Please allow up to seven days before contacting us about a late delivery at **help@magazinesdirect.com**

Circulation
Head of Newstrade **Ben Oakden**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Senior Advertising Production Manager **Jo Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Nick Williams**

Management
Chief Growth Officer **Claire MacLellan**
Managing Director **Sarah Rafati Howard**
Content Director **Gemma Lavender**
Head of Art & Design **Greg Whitaker**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

All contents © 2022 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

Widely Recycled

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill and paper hold full FSC and PEFC certification and accreditation.

FUTURE
Connectors. Creators. Experience Makers.

Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief Executive **Zillah Byng-Thorne**
Non-executive Chairman **Richard Huntingford**
Chief Financial Officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

ipso Regulated

Smithsonian

CORGI®
WWW.CORGI.CO.UK

CS91304 1903 Wright Flyer

CS91301 Bleriot XL Monoplane

CS91303 Amelia Earhart's Lockheed® Vega® 5B

PRE-ORDER NOW!

THE HISTORY OF HUMAN FLIGHT IN ONE COLLECTION

©2021 Smithsonian Institution. The name "Smithsonian" and the Smithsonian logo are registered trademarks owned by the Smithsonian Institution.

To find out more about the Smithsonian range and the entire Corgi collection, contact our Sales Office now on **01843 233525/sales@hornby.com**

Sky-Watcher®

Be amazed.

POPULAR BEGINNER & INTERMEDIATE TELESCOPES

"This telescope made observing the night sky enjoyable....great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE GROUP TEST WINNER

ASTROLUX 76mm f/9.2 REFLECTOR
SRP £179

MERCURY-707
70mm f/10 REFRACTOR
SRP £119

CAPRICORN-70 (EQ1)
70mm f/12.8 REFRACTOR
SRP £149

"Meets all expectations and is the perfect starter scope"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-130 (EQ2)
130mm f/6.9 REFLECTOR
SRP £225

SKYHAWK-114 (EQ1)
114mm f/8.7 CATADIOPTRIC REFLECTOR
SRP £109

EVOSTAR-90 (AZ3)
90mm f/10 REFRACTOR
SRP £219

EVOSTAR-90 (EQ2)
90mm f/10 REFRACTOR
SRP £229

EXPLORER-150P (EQ3-2)
150mm f/5 PARABOLIC REFLECTOR

"Good for advanced observing... Saturn was a stunning sight"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE HIGHLY COMMENDED 87%

SRP £468

EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR

"Passed all our tests with flying colours and was a delight to use both optically and mechanically"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE GROUP TEST WINNER

SRP £699

HERITAGE-150P FLEXTUBE™ (VIRTUOSO GTI)
150mm f/5 Wi-Fi GO-TO PARABOLIC DOBSONIAN
Wi-Fi
SRP £399

SKYMAX-127 (VIRTUOSO GTI)
127mm f/11.8 Wi-Fi GO-TO MAKSUTOV-CASSEGRAIN
Wi-Fi
SRP £549

"Turning to Saturn, the view really took our breath away....The Skyliner was a joy to use"
BBC SKY AT NIGHT MAGAZINE

SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN

Sky at Night MAGAZINE HIGHLY COMMENDED 93%

SRP £419

SKYLINER-250P CLASSIC
254mm f/4.7 PARABOLIC DOBSONIAN
SRP £619

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 111 August 2014

HERITAGE-76
76mm f/4 DOBSONIAN
SRP £79.99

HERITAGE-100P
100mm f/4 PARABOLIC DOBSONIAN
SRP £135

HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN
SRP £205

HERITAGE-150P FLEXTUBE™
150mm f/5 PARABOLIC DOBSONIAN
SRP £255

Email for 88 Page FREE Catalogue

OVL

Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk

9021

9000